RAILWAYS

AND

LOCOMOTION.

BRIDGE OVER THE WYE.

RAILWAYS

AND

LOCOMOTION.

BY THE

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INTRODUCTION.

To trace the progress of some great invention from its origin in the parent mind, through its several stages of development to its arrival at maturity, is an exercise which offers an ample recompense for the time and labour bestowed upon it. No subject of investigation, perhaps, is more fraught with interest than the History of Inventions; a history abounding with passages of stirring narrative and romantic incident; a history of successful exercise of the mightiest intellectual powers; a history which too often chronicles the misfortunes of the inventor, while it records the vast benefits conferred on mankind by his genius or research. The remark, that "Truth is stranger than Fiction," finds abundant illustration in the history of inventions; and if the ancients loved to invest with mystery, and to hand down in fable, the discoveries of early science, (as when, for instance, by the legend of waxen wings of Icarus, they immortalized the invention of sails,) so in modern times many a tale of strange adventure, many a romance of real life, is associated inseparably with some happy contrivance or skilful adaptation, which adds to the comforts, or lessens the evils of our lot.

Nor is the history of an invention less instructive, or less worthy of investigation, when it lacks the peculiar interest derived from the personal adventures or struggles of its first author; nay, perhaps it gains, in this case, a new charm,—the charm of mysterious origin, of contested paternity. Great inventions may not be unfitly symbolized, perhaps, by the mighty rivers of the globe. Of some of these, the sources are entirely unknown; of others they are suspected or are fixed by probable conjecture; while the rest have been traced to their very birth by adventurous travellers, who have quaffed the limpid waters bubbling forth from some green hillock, and have crossed with easy step the rill which is destined to fertilize a continent. Thus, while the origin and progress of some of man's great discoveries are clearly marked upon the map of history, we soon lose in tortuous windings, all trace of others. The Invention of Printing (at least in its present form), is one of those which we can perhaps accompany throughout its whole course. From its source in the mind of Guttenburg, we follow the increasing stream, marking each tributary which it receives, each obstacle which it overleaps, until it becomes too mighty for its banks, and spreads itself over the civilized world, bearing unspeakable blessings on its bosom. The Steam Engine may perhaps be selected as an example of an opposite kind. Amid the mists of antiquity that mighty power is first dimly shadowed forth,—which in modern times has revolutionized the habits, the commerce, the warfare of nations,—which has bridged the ocean,—which has altered so much the relations long subsisting between time and space. A cloud hides its origin: and though all its vast achievements belong to our

own times, we are still in doubt whether the Philosopher of Alexandria records the invention in his own time, or the pre-existence of that simple machine of which the modern Steam Engine is the magnificent development.

It is, perhaps, unnecessary to adduce examples of inventions of which the origin and early history are entirely unknown; we may well suppose some of the arts of life to have been taught *to* man, not devised *by* him; we know that the use of skins for clothing was the subject of Divine suggestion. The ark, which may possibly have been the model for the earliest ships, was built by the directions of the Almighty. The common implements of husbandry, the management of horses, the use of wheeled chariots and waggons, the measurement of time,—all these date from a period of the world's history so remote that we are constrained to regard them with a degree of doubt, whether they may not have been born with the mind, rather than discovered by its powers.

The invention which we propose to trace in this volume must be placed in the category of those which own no certain parentage, and which are associated with no one master mind. Yet the uncertainty which hangs over its birth is not occasioned by the lapse of time; our own days have witnessed the enormous expansion of a principle which was in its infancy when we too were children; an expansion, which for rapidity of operation and vastness of influence, is without a parallel in the annals of science. And though no one name will be handed down to posterity, as that of the Inventor of Railways,—though no Arkwright or Watt has identified his name with their history, or founded an imperishable monument of his genius

in their establishment, yet there are not wanting circumstances which lend a magic interest to the humble beginnings and cautious advances which heralded the approach of one of the greatest mechanical appliances which the world has seen. The iron track on which we traverse a county or a province with more ease than the wildest fantasies of the veriest dreamer could have imaged to our grandfathers, owes its present perfection to the united efforts of many great minds, each contributing to the successful accomplishment of the end in view; and we may therefore regard the existing work with the same feelings with which we should contemplate a picture, the joint production of several great artists,—the landscape by a Gainsborough—the animals added by a Landseer—the graceful human figures by an Etty. The modern Railway is a presentment of the combined powers of the greatest engineers, and it cannot but be peculiarly interesting to note the share contributed by each to the mighty work, the portions of the painting which betray a distinctive origin.

Perhaps this joint exercise of genius was never more remarkably illustrated, than in the erection of that wonderful tube which affords the means of transit to railway trains over the Menai Straits. Two of the most distinguished engineers of the present day, Mr. Brunel and Mr. Locke, were then seen acting as the cheerful assistants of one who well deserves his world-wide reputation,—Mr. Robert Stephenson.

THE RAILWAY SYSTEM.

CHAPTER I.

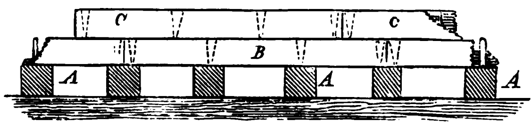
RISE AND PROGRESS OF THE RAILWAY SYSTEM.

ALTHOUGH the last thirty years have witnessed the rise and unexampled growth of the Railway system, which now covers England with an iron net-work, yet we must go back to the last century for the first employment of iron in road-making; and even to a still earlier period for the first application of the principle on which a railway is based, viz. the interposition of some smooth continuous body between the carriage-wheels and the ground.

We cannot recognise the germ of the railroad in the "Appian Way," which was formed by blocks of stone fitted closely together, because this, after all, was but a method of smoothing the surface of the ground itself, for the passage of ordinary vehicles, horsemen, and pedestrians; while the very definition of a Railway denotes the placing of continuous bars or rails on or above the actual soil, and traversed by wheels specially adapted to them. Nevertheless, the object of both these expedients is the same, namely, to diminish friction by providing a smooth track for the wheels; and it is natural to suppose, that wherever heavy loads had to be frequently carried over the same ground in wheeled vehicles, there the greatest efforts would be made to lessen the labour of draught by smoothing and hardening the surface of the road.

Accordingly it was among the collieries of the great Northern coal-field, that railways were first constructed; and perhaps the obscure workman who first laid down planks to facilitate the passage of carts over some rough spot, deserves to be honoured as the "Inventor" of the Railway. By whomsoever suggested, however, it is certain that a rude railway of wood was in use for the conveyance of coals from the pits to the river Tyne, as early as the year 1676. Roger North, in his Life of the Lord Keeper North, tells us that these roads were constructed "by laying rails of timber exactly straight and parallel; and bulky carts were made with four rollers fitting those rails, whereby the carriage was made so easy that one horse could draw four or five chaldrons of coal." It would appear that the rapid wear of these wooden ways was in some degree obviated, by using a double thickness of wood, the principal rail being overlaid by a covering which could easily be renewed without derangement of the whole; and the advantages result-

Fig. 1.



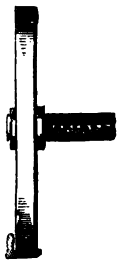
A, SLEEPERS; B, PRINCIPAL RAIL; C, UPPER RAIL.

ing from the use of these timber ways were so great that they were speedily established throughout the mining districts of Northumberland and Durham.

One hundred years passed away before any important improvement was effected in the wooden roads: but the year 1767 witnessed a vast stride in

advance, by the adoption of an iron covering or plating for the surface of the upper rail. This alteration, which at once enabled the horse to take double his previous load, was not introduced at Newcastle, as is generally supposed, but at Colebrooke Dale, in Shropshire. It appears from a letter of the ingenious Mr. Hornblower, the contemporary and rival of Watt, written to a Committee of the House of Commons in that year, that the Colebrooke Dale Iron Company adopted this method rather as one of economy, than in the expectation of realizing any striking improvement in the facility of transit: but the superiority of the iron-plated rail over its wooden predecessor speedily became apparent, and its immediate adoption in the mining districts followed as a matter of course. The iron plates used appear to have been about four inches wide, and one inch and a quarter thick.

Fig. 2.



WHEEL ON TRAM-PLATE.

Nine years later, viz. in 1776, Mr. Carr introduced the use of "plate-rails," —now usually termed "tram-plates," that is, cast-iron plates with a ledge or upright rib to confine the waggon-wheel to the track. These were nailed to wooden sleepers or supports, for which stone blocks were soon substituted.

It is obvious, that these tram-plates had one great disadvantage:—stones or dirt were liable to be lodged upon the plate, to the serious obstruction of the wheels, and to the great loss of power expended in the draught. A remedy for these evils was found in the Edge-Rail. We cannot fix with accuracy the period of its introduction: but

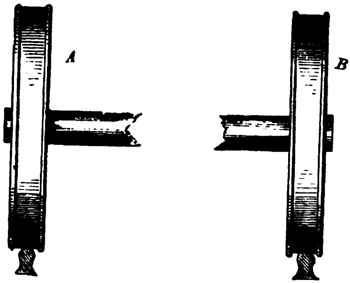
it was used in a railway constructed in 1800-1, for the conveyance of slate from the Penrhyn quarries to the port of Bangor, in North Wales. Ten horses were able to do the work on this railway, which had previously required the constant labour of four hundred!

The superiority of the Edge-Rail over the old tram-plates was so obvious, that it was speedily adopted in all the collieries of England. The rails were of cast-iron; for the method of constructing them from wrought-iron bars, now in use, was not introduced until 1830. Those which were laid down at the Penrhyn slate quarries were elliptical or oval, in the form of their cross section; the longer diameter being two inches; the shorter, one inch and a half. They were cast in lengths of four feet six inches, each of these lengths weighing 36 lbs., and were secured to the sills, or sleepers, by a projecting piece at each end. The waggon wheels used on this railway were also of cast-iron, and were provided with a groove or hollow which fitted the upper surface of the rail: but it was found that this groove was subject to a very rapid wear by its contact with the oval edge which it traversed; and that a serious amount of friction was caused by the tightness with which the wheel and rail became fitted to each other after some months' use. To remedy this defect, an alteration was made in the form of the rail and of the cast-iron wheels. The oval edge was flattened, so as to present a plane surface; and the periphery, or outer circle of the wheel, instead of presenting a hollow groove, was simply provided with two flanges, or ribs, which prevented its escape from the track. This amended arrangement will be fully understood by an inspection of Figure 3; in which A represents a wheel upon

the oval edge of the rail as first constructed: B shows the change or improvement of the flattened edge.

We have been particular in our description of

Fig. 3.



this early form of the Edge-Rail, because its introduction was certainly a most important epoch in the history of railways. Practical men began to perceive the value of the principle which it illustrated, and the extension of the railway system to the general purposes of commerce became, for the first time, a favourite project with men of enterprising and active minds: the invention—if such it can be called—emerged from the murky obscurity of coal-fields and slate-quarries, and made its appearance, under the auspices of men eminent in science or commerce, as one of the happy discoveries of modern time.

To the merchants and traders of two provincial towns must certainly be accorded the honour of first proving, by a costly experiment, the value of a railway as a means of general transport for passengers as well as goods. The year 1825 witnessed the completion of the railway between the towns

of Stockton and Darlington, in the county of Durham; and though the interests promoted by this railway were local, and its length not greater than twelve miles, yet the immense traffic which rewarded its projectors, and the impetus which it gave to the trade of the port of Stockton, attracted the eyes of engineers and commercial men to it in a remarkable degree, and gave it an importance which it would not otherwise have possessed.

For some time after its completion the passengers were conveyed in vehicles of the ordinary construction, closely resembling the stage-coaches used on turnpike roads. Each coach was drawn by one horse, which cantered easily along when its load was once put in motion: and the speed of the vehicle was checked, or its stoppage effected by using a "break" or long lever which pressed a wooden block forcibly against the periphery of the wheel. The strange appearance of these vehicles, —half stage-coach, half railway waggon,—can never be forgotten: while their curious intermingling of the "road and the rail" marked the transition which was then in progress from the old mode of travelling to that which has now so completely superseded it. We should add, that the coach was never turned round, the horse being attached to either end of the vehicle with equal facility;—an arrangement which must, no doubt, have proved perplexing to those inside passengers who were unfortunately unable to sit in comfort with their "backs to the horses."

The immense traffic, however, which found its way along the line of the Stockton and Darlington Railway soon led to the substitution of more commodious and efficient modes of conveyance. The Locomotive Engine, with its train of carriages,

soon superseded the horse-coach: and the present writer well recollects the astonishment and pleasure with which he accompanied a large party in a trip along the line for the express purpose of testing the new mode of travelling, soon after its introduction. The line is now a mere link in one of the vast chains which unite the northern abodes of industry with the metropolis: but it must ever be regarded with interest, as the first successful attempt to extend the benefits of the railway system to the public at large.

It is remarkable that London, the chief city of the world, the greatest and wealthiest of all capitals, has seldom occupied the van in the march of improvement in those arts which contribute to our comfort or prosperity. The streets of London, for instance, still displayed the wretched oil lamps which only served to render darkness visible, while those of Newcastle-upon-Tyne were brilliantly illuminated by the newly invented coal-gas. It might have been supposed, that the merchants of London,—the "princes" of the greatest commercial nation of modern times,—would have been amongst the first to seize the advantages offered by railway communication; and that London would have been the nucleus, or starting-point, of many lines, which, like the fibres of a plant, would have gradually extended themselves further and further from the parent root. The facts, however, are strangely at variance with this very natural supposition; the railway system first sprang up, and attained its full growth in the provinces; and as two towns of minor note in the county of Durham first set the example of railway intercommunication; so two other provincial towns—the important towns of Liverpool and Manchester—next claim our atten-

tion, and deserve our gratitude, for the zeal and energy with which they advanced and extended the system which has since produced such beneficial results. It may be worth while to remark, in passing, how singularly this feature in the progress of railways illustrates a peculiarity in the British character. In France, and indeed in all the continental countries, projects of this nature emanate from the government, and need its powerful support and fostering care, not only for their establishment, but for their subsequent maintenance: in England, private enterprise has invariably originated great public improvements; and jealousy of government interference has been carried so far, as to have given rise to serious inconvenience, as we shall hereafter have occasion to show. The men of Liverpool and of Manchester did not wait for the example of the men of London: still less did they seek or expect any aid from the government of the country, beyond a grant of the necessary legal powers before commencing their railway: and we venture to refer to this as a proof of the healthy independence and activity engendered by free institutions, which render it impossible for any man, or body of men, possessing energy, skill, and perseverance, to fail in the accomplishment of any object of lawful enterprise.

There are no other two towns in the kingdom between which the commercial intercourse is so close and so vast, as between Liverpool and Manchester. From the port of Liverpool, Manchester receives all her supplies of raw material; while a very large portion of her manufactured goods are returned to the same port for shipment to all parts of the world. It was thus obviously of the utmost importance to the interests of all connected with

the cotton trade that a cheap and rapid communication should be maintained between the two places; and it would appear that the project of a railway between them was entertained as early as the year 1822. The scheme, however, had to encounter a violent opposition from parties interested in the old modes of conveyance: nor was it until the year 1826, that the necessary powers were obtained for the commencement of the work. Every year, however, had demonstrated more clearly the necessity for increased facilities of communication. The average length of passage by canal was thirty-six hours; and so great was the irregularity and uncertainty of transit, that the cotton spinner was obliged to keep large stocks of raw material on hand, lest his mills should be stopped through failure in the delivery of the bales by the carriers. By the projected railway, this serious inconvenience would be removed; it was estimated that the time of transit would be reduced to two hours, and thus Manchester would possess nearly all the advantages of a sea-port, since goods could be delivered into a warehouse at Manchester on the same day that they were landed at Liverpool. In commercial transactions, a saving of time is almost always a saving of money. It was computed that the cost of carriage of goods between the two towns would be reduced one half by the establishment of the railway: and as the amount saved would be deducted from the price of the manufactured goods, this might fairly be considered as a public or national gain.

All opposition having been at last overcome, the work was commenced, in June 1826, under the superintendence of Mr. George Stephenson. The difficulties which presented themselves were of no

ordinary character. Unlike a turnpike road, which admits of declivities or slopes of greater or less steepness, and of angles more or less abrupt, a railroad can seldom be permitted to deviate much from a straight line, and from a level surface. The fulfilment of these conditions on the proposed line between Manchester and Liverpool involved operations of the most formidable and costly description, and though greater engineering triumphs have been achieved by Mr. Stephenson's successors, it cannot be denied that to him, and to the company for whom he acted, must be accorded the honour of pioneering in the yet untrodden field of railway enterprise, in which others have followed him with increased success. Any sketch of the history of railways would be quite incomplete without some brief notice of the obstacles surmounted by perseverance and skill in the construction of this great work.

The distance between the two towns is thirty-one miles; and in traversing this distance, tunnels were to be made, hills to be levelled, valleys to be filled up, and rivers to be crossed. Last, but not least, a moss, or bog, four miles in extent, nearly midway between the two towns, presented a barrier which by many competent judges was deemed impassable.

"Chat Moss" has acquired an historical interest in the annals of railway engineering. It is a barren waste, having an area of about twelve square miles, so soft and spongy, that cattle could not tread upon it with safety. In some parts, it was said that the moss was so fluid, that an iron bar, if laid on the surface, would gradually sink to a depth of from ten to thirty-five feet. It was on this treacherous bog that a railway was to be con-

structed, capable of bearing the enormous loads which it was the express object of the projectors to convey along it!

Mr. Stephenson commenced his operations in the face of this formidable difficulty by digging deep drains, parallel with the line of road: but the softness of the moss baffled all attempts at ordinary draining. In one part, where it was necessary that an embankment of about twenty feet in height should support the railway, many thousand cubic yards of earth were thrown upon the surface, and sank to the bottom, before a firm foundation could be gained: so that the whole embankment, instead of being twenty feet in height, extends perhaps from thirty to fifty-five feet in depth from the base to the level of the rails. In another part, where the moss bore the ominous name of the "Flow Moss," hurdles and brush-wood were laid upon the treacherous surface: on these a roadway was formed of sand and gravel, which supports the wooden sleepers of the rails; and the whole may be said to float on the semi-fluid and yielding mass beneath. These unparalleled difficulties, which would have disheartened a less daring and experienced engineer, were at length surmounted: the road became gradually consolidated; and an experience of twenty-three years has proved that this portion of the line is not inferior to the rest in durability and safety.

If the reader should ever traverse the Liverpool and Manchester Railroad, he will easily recognise the dreary waste of Chat Moss. He cannot but marvel when he reflects that by the ingenuity and perseverance of man, trains of carriages and waggons of many tons in weight are now con-

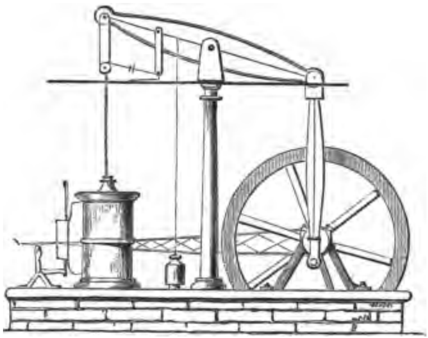
stantly passing and repassing over a bog which originally would not admit of a person walking over it except in the driest weather!

In the next chapter we may have occasion to refer to the tunnels, excavations, and embankments which were found necessary in this great undertaking: it may be sufficient now, to give the reader some idea of the magnitude of the work, by stating, that nearly *four millions of tons* of stone, clay, and soil, were dug out of the various cuttings, and used in the formation of the line. The total sum expended was 820,000*l.* or upwards of 25,000*l.* per mile.

The opening of the railway took place in 1830. The perfect success of the undertaking, both in an engineering and a commercial point of view, gave a vast stimulus to the projectors of similar works: and we may close this chapter by stating the remarkable fact, that during the ten years which succeeded the opening of the Liverpool and Manchester Line, not less than 107 bills were carried through Parliament for the construction of railways in Great Britain and Ireland. Of these, the London and Birmingham Railway, opened in 1836, was perhaps the most important. The "Grand Junction" connected Birmingham with Liverpool and Manchester, and therefore opened a communication between those important towns and the metropolis. These separate undertakings, however, together with many others, are now merged in the great iron highway known as the London and North Western: while other trunk lines, hardly inferior in extent and importance, penetrate the Southern and Western counties. The chain of railway communication may now be said to

approach completion; and as regards the speed, safety, and comfort of railway travelling, little is left to be desired.

In a subsequent page we shall have occasion to revert to some of the manifold advantages which have resulted to the community at large from the universal adoption of this mode of travelling.



CHAPTER II.

CONSTRUCTION OF A RAILWAY.

In the last chapter, we have glanced at some of the difficulties encountered and overcome in the construction of the Liverpool and Manchester Railway. We have now to lay before the reader, as briefly as may be consistent with clearness, some details of the many ingenious mechanical appliances which have to be brought into play, and of the many well-considered plans to be carried out, before a new line of railway can be brought into safe operation. We shall confine ourselves, in this chapter, to the subject of the first construction of the road itself; reserving all notice of the actual iron track, and of the engines and carriages which traverse it, for a subsequent one.

It is evident, that in many respects the construction of a railway, and of a canal, present points of similarity: both, for instance, involve the arduous and often difficult process of tunnelling. But in one essential respect, the construction of a railway differs from that of a canal,—namely, in the absolute necessity for preserving a nearly level surface. Our readers are of course well aware that canals are conducted over steep eminences by the contrivances called Locks: by means of a chain or series of locks, an ascent or descent of 100 feet, or more, of perpendicular height may be effected, with a loss, indeed, of time in transit, but with an

immense saving of labour and cost in the first formation of the canal. The Railway engineer, however, can resort to no such expedient. It is true, that a kind of "railway lock" has been suggested for the transference of trains from a lower to a higher level at once,—per saltum: and it is clear, that any contrivance which enabled us to *raise* such a load, would enable us also to lower it to its original position: but the idea has found no favour with practical men, and is quite laid aside and forgotten. The speed and regularity so characteristic of railway travelling would not admit of so tedious a mode of surmounting an intervening eminence: we may imagine the grumbling which would ensue among the passengers by the "Down Express," if they were required to sit patiently on a cold January day while the engine, the tender, and twenty carriages were raised or lowered through the lock, or series of locks!

The Railway, it is evident, can only surmount the eminence,—(we ask pardon for the Hibernicism)—by going through it: and the reader will see that one of the most arduous and responsible duties of an engineer is, so to plan out the proposed line that the excavations, or "cuttings," may be nearly equal in cubical content, to the "embankments," or raised causeways over valleys and depressed portions of the country, in order that the soil dug out of the one may supply materials for the other. If this preliminary calculation were not carefully conducted, the engineer might find himself in the very awkward predicament of having to construct a long and high embankment without materials; and might consequently be obliged to waste time and labour in digging extensive and useless trenches merely for the sake of the soil thrown out of them.

In addition to this balancing of cuttings and embankments, the engineer has to consider the level at which the line must cross the various rivers and canals in its course, so as not to interfere with the navigation: if he has to effect a junction with another railway, he must duly consider, beforehand, the level of that railway at the point of proposed junction: and yet if he has to *cross* the same or another line, he must contrive to do so at a considerable elevation, as "level crossings" are attended with much danger, and are very properly condemned by the legislature.

These difficulties, then, meet the engineer at the very outset, in mapping out his proposed line: we wish he were not embarrassed by other difficulties, much more vexatious, arising from the opposition of landed proprietors, or the conflicting interests of rival towns.

The senseless outcry which was raised when railways were first extensively projected, must be recollected with feelings of shame and astonishment even by those who were foremost amongst the opposers of the "innovation." The nineteenth century saw a revival of the same spirit which clamoured for the destruction of printing-presses, as ruinous to the interests of the ink-makers; or for the suppression of stage-coaches, as fatal to the breed of riding-horses, and to the trade of saddlers: the same spirit which in more recent times led to the sacking of cotton-mills, and the burning of threshing machines. The wrongs of coachmen, guards, horse-keepers, roadside inn-keepers, *et id genus omne*, were set forth with harrowing minuteness: the noble sport of fox-hunting, it was said, must now "cease and determine" throughout the length and breadth of the once merrie England;

and country gentlemen bewailed over their port the waning glories of the chase, marred by the mighty and pernicious powers of Steam and Iron!

We can afford to smile at this by no means exaggerated account of the misapprehension which was once so prevalent, when we see how the predictions have been falsified by the result. The coachmen, guards, and horse-keepers are now employed on the various railways, with easier work and better wages than before; or they find ample means of subsistence in the conveyance of passengers to and from stations; or they are ensconced as keepers of snug and profitable "Railway Hotels." The anticipated decline of fox-hunting must still be distant, when we see parties of eager gentlemen, in "pink," engaging special trains to convey them and their steeds to the vicinity of "The Meet:" or returning in the evening, flushed with the achievements of the field and bespattered with its mud, to relate their daring exploits to wondering sisters thirty miles off! *

Although, however, we can now afford to jest at the expense of the opposers of railways, the violent opposition to his proceedings was no subject of jest to the engineer entrusted with the charge of mapping out a new line. Some few proprietors of land carried their resistance so far as to treat with actual rudeness and violence the persons engaged in making the requisite surveys. The opposition in Parliament was conducted with a zeal and energy worthy of a better cause; and many thousands of pounds were frequently spent before permission could be obtained to commence a work

* The engagement of a special train to meet the hounds is a well-known fact in ——shire: and may possibly be one of ordinary occurrence elsewhere.

which would bring incalculable benefits to tens of thousands of the population. £80,000 were expended in Parliamentary expenses by the Great Western Company alone!

We are justified, then, in mentioning, among the most formidable and vexatious difficulties of the engineer, the opposition which he encountered,—for we hope we may now speak in the past tense,—from the owners of the land. Unhappily, however, though active opposition may have ceased, its effects remain, and in many instances have recoiled, with justice, upon the heads of the opposers. A striking example of this retributive justice is pointed out by Sir F. B. Head, in his lively and interesting little work, "Stokers and Pokers." The London and Birmingham line, as originally planned, would have passed close by the large and flourishing town of Northampton: but so effectual was the opposition of the inhabitants that the route was altered, and the town avoided, at the expense of constructing a very long tunnel. The inhabitants of Northampton have now, probably, discovered their mistake. They pay the penalty of their error in the inconveniences and delays of a branch railway, four miles in length, from their town to the main line which they took such pains to thrust away from them.

The reader will perceive, by this time, that the labours preliminary to the commencement of a new railway are of no ordinary kind. We have said nothing of the innumerable legal forms with which it is necessary to comply: the countless plans, sections, and maps which must be prepared for the information and satisfaction of land-owners, parishes, county authorities, Railway Commissioners: the Notices, Advertisements, and other endless an-

nouncements which the law requires, no doubt properly enough, to be duly made before it suffers any interference with the rights of property.

We will suppose all these preliminaries despatched; and with a sense of relief, shared probably by our readers, proceed to the actual construction of the line.

The "turning of the first sod" having been duly accomplished by some distinguished personage, with polished spade and mahogany wheelbarrow, the good dinner and indifferent speeches with which every English undertaking must be inaugurated having been respectively enjoyed and endured, the business of road-making commences in good earnest. The engineer-in-chief musters his forces: for as in the warfare of nations the most brilliant military talents would be useless unless backed by adequate numbers of well-disciplined troops, so in the proposed attack upon the natural defences of the line of route, the assistance of trained battalions of sturdy labourers is requisite for the success of the campaign. The engineer-in-chief is of course the general or commander: he has around him his "staff" of assistant-engineers, each filling some place of important command. These, again, direct the operations of overlookers, foremen, and master-workmen; while the "rank and file" of this peaceful army consists of labourers,—men of muscular build, and of vast powers of endurance;—a peculiar race, unknown before the great works were projected which now remain as monuments of their industry.

The railway labourer has doubtless gained his well-known soubriquet of "navvy," from having been first employed in the construction of the great canals, or navigations, (as they were often called,)

so many of which were completed about the commencement of the present century. As in the affairs of the political world situations of great difficulty and crisis invariably call forth men competent to cope with them, so the necessity for human labour of unexampled extent, created by the projection of these great works, seems to have called into existence a race of men specially adapted for the occasion. The ploughman, or thresher, who plods through his day's work at the farm, would be amazed to see the rapid movements and prodigious energy of these men. A careless and thoughtless race they are, resembling much the sailor in character:—highly paid for their herculean labours, they spend their few hours of leisure in recruiting their strength for the next effort by feasts of the most substantial kind, in which even expensive luxuries are not forgotten:* and we fear the remembrance of a future possible "rainy day," or the wisdom of providing against those changes and chances of this mortal life to which he is so peculiarly liable, seldom enters into the calculations of a navvy.

The present writer was brought much into contact, a few years ago, with this peculiar race of men, during the construction of a railway through a part of his parish: and he has pleasure in stating that he found, in all with whom he conversed, an honest bluntness and hearty good-will, which greatly won upon his regard. Several poor fellows, victims of the frightful accidents which occasionally occur in works of such magnitude, he attended on their death-beds; and the result of this intercourse was,

* Young ducks and green peas, for instance, at a period of the year when such delicacies command high prices. (This is written from actual observation.)

on the whole, a favourable impression of the character of the navvy. Many of these men had remained for several years in the service of the same master,—Mr. Brassey, the eminent contractor; and had been employed in the formation of the Paris and Rouen, and other foreign lines: and it was not a little curious to hear the strange jargon of French and English jabbered by the urchins who played in the village of temporary huts inhabited by their sires. A salutation in French drew an immediate answer in the same language from the little creatures, and secured a welcome to the speaker.

It may here be observed, that the system of Contracts is one universally adopted in the construction of Railways. The engineer's plans and specifications are confided to men possessed of the requisite capital, skill, and experience, for carrying them into effect: these men, again, sub-let portions of the line, or particular works, to other contractors, who find their profit, (or, occasionally, their loss,) in the difference between the sum named in the contract, and that actually expended in the work. Thus the labourers are really the servants of the contractor: but the whole work is, of course, vigilantly superintended by the engineer and his assistants; who take care that the interests of the Company and the safety of the public are not sacrificed to private gain.

Such is the host whose duty it is, literally, to form "practicable breaches" in the ramparts which obstruct the line of march laid down by the general-in-chief. Their weapons are the mattock, the spade, and the barrow: but the mighty agency of steam is soon called in to aid in the operations. Perhaps the nature of railway works will be best

understood by a description, sketched from frequent personal observation, of the mode of forming a tunnel, a cutting, an embankment, and other great features of a line passing through an uneven country.

A tunnel, of any considerable length, is invariably formed by first sinking shafts, or perpendicular wells, from the surface of the ground to the level of the proposed road; and by then excavating or burrowing laterally in the proper direction, until the several separate passages meet, and a continuous way is opened through the hill. The sinking of these shafts, then, is the first operation: a steam-engine is erected over or close by the mouth of each shaft for the purpose of lowering the men, and of raising the soil excavated: tram-roads are laid down both above and below-ground, for the conveyance of bricks *to* the shaft, and of rubbish *from* it; and while the bright sun shines on green fields at the surface, far below it the dark passage is widened and lengthened unceasingly by gangs of men, who relieve each other at their mole-like labours, night and day.

The unerring exactness with which the work is "driven" cannot but excite a feeling of admiration in those unacquainted with this kind of scientific operation. It might well be thought, that some little deviation from the precise level or direction could hardly be avoided by men working underground by candlelight: it might be expected, that when two separate lengths of the tunnel were completed, and the gangs of men found themselves face to face, some little irregularity in the junction would be detected, and passed by as unimportant: but such is the accuracy of modern engineering, that a divergence even of one inch from the exact

line marked out is almost unknown. The junctions in every case are perfectly correct; and when the brickwork is completed, no trace remains of the place where science effected this really astonishing though unnoticed achievement.

It is evident, that the difficulties of the work may be immensely increased by unforeseen peculiarities in the strata through which the tunnel is driven. The formation of a tunnel through solid rock, though it may appear an undertaking of tremendous labour, is really far less formidable, and ultimately far less expensive, than the construction of a safe and dry passage through loose and crumbling strata, full of springs and quicksands. The rock requires no artificial support; brickwork is unnecessary; nay, the stone quarried in the tunnel itself may build a bridge or face a cutting. But the loose flowing ground is with difficulty supported until the brick arch can be formed: the work proceeds amidst the most imminent dangers from the breaking in of the roof, and the influx of torrents of water: the hardships endured, and the perils encountered by the men and their officers, would hardly be believed by those who have not witnessed them. The courage and determination of the men, under these circumstances, rise to a species of enthusiasm. The efforts they make are really almost superhuman. Up to their throats in water, they have been known to continue, with desperate energy, their efforts to stop the torrent, and have at last narrowly escaped with life by swimming through the flooded tunnel.*

Several years ago, the writer spent some hours in that wonderful work, the Thames Tunnel, then about half completed,—that is to say, at the most

* See Sir F. B. Head's work, already quoted, p. 20.

dangerous and critical point of its progress. The scene was one never to be forgotten. The loud noise of rushing water, which conveyed to the visitor the idea that the river was bursting in upon him; the shouts of the men at work in the "shield,"—one of the most ingenious and original contrivances ever devised; the figures, dimly seen by the glimmer of candles, all in attitudes of rapid and unceasing exertion, made up a scene which impressed itself indelibly on the memory. And though the Thames Tunnel was, indeed, a work in every way extraordinary, yet difficulties hardly less formidable, and dangers little less appalling, have been boldly met in the construction of more than one of those subterranean passages, which we now traverse in a luxurious carriage, well lighted, at a speed of fifty miles an hour! For our own part, we must say, that while making this transit, our thoughts not seldom wander back a few years to the time when men spent so many long months in that dreary passage; and to the memory of the poor fellows who fell in the prime of life and strength, by some unhappy accident, in providing us with that astonishing convenience and luxury. Twenty-six lives were lost in the construction of the Kilsby Tunnel! At such a price are our comforts purchased.

It is probable that we shall not have to go far from the mouth of the tunnel, in order to witness the excavation of a cutting, and the formation of an embankment, works which are invariably carried on in concert, for the reason stated in a previous page. In almost every instance, a cutting of greater or less depth conducts the line to the point at which the tunnel commences; for as a general rule, a tunnel is not considered necessary

until the cutting exceeds a depth of sixty feet. Many considerations, however, may induce an engineer to prefer a cutting to a tunnel even for greater depths than sixty feet; while, on the other hand, the great spread of the cutting at the top, rendered necessary by certain conditions of the ground, or the danger of the sides slipping down upon the rails, may cause the adoption of a tunnel for depths comparatively shallow.

At any rate, the place for commencing the cutting having been determined, a tram-road is laid from the spot to the brink of the valley or depression over which the nearest embankment is necessary. And now ensues a very curious and busy scene, which some of our readers may often have watched, as we have, with interest. The soil, excavated with the mattock and shovel, is thrown upon waggons specially contrived for the purpose. The body of the waggon is attached to the frame-work by a hinge or spindle, in such a manner that while the wheels remain stationary, the body may be tilted up, and may discharge its contents, much in the same way as is done with ordinary carts. A short train of such waggons, loaded with soil, is drawn by horses along the tram-road to a point at a short distance from the brink of the embankment. There they are halted, and the following curious *performance* (for we can call it by no other name) takes place. The driver attaches a horse to a single waggon; he urges him to a violent effort, and at a full trot or even canter approaches the brink: when at about twenty yards from the edge, he dexterously unhooks the traces; the well-trained creature jumps aside nimbly, the waggon rolls forward with increased momentum; when close to the edge, two attendant navvies with

a couple of blows loosen the body from the frame and the tail-board from the body; at the next moment the wheels strike a sleeper, firmly secured across the tram-plates, and the shock upsets the load and even throws the hind-wheels of the waggon into the air, the soil rolling down the bank into the valley below. The empty waggon is then slowly drawn out of the way, and the process is repeated with the remainder of the train. To a bystander, this mode of procedure appears hazardous to both horses and men; and more than once, indeed, we have seen the poor horse severely injured by a blow from the ponderous waggon, when he has failed in the performance of his often-repeated lesson. While watching the busy scene, the idea has frequently occurred to us, that the distribution of the soil might be effected with greater safety, and at the same time with greater accuracy, by using frames of timber, resembling gigantic ladders, laid horizontally upon the completed portion of the road, and projecting over the brink, being supported near their extremity by piles temporarily driven into the loose soil. The loaded train being drawn upon the hinder or inner end of these frames, would effectually prevent that end from leaving the ground; and each loaded waggon might then (as it appears to us) be run out upon the projecting part, when, a door being opened in the bottom of the waggon, the contents would be discharged upon the exact spot where they were required. The timber frames might be advanced by the action of screws, or other adequate mechanical power. We mention this idea as one that has occurred to us while commiserating the severe toils of horses and men, under a broiling sun in July or August: but probably the eminent practical men who conduct

these matters could show ample reasons for preferring the plan first described.

Day after day, and week after week, the operations are diligently carried on: the almost mountebank feat with the horse and waggon is repeated many thousands of times, until as the cutting advances further into the hill, the embankment makes visible progress in its slow march across the valley. Meanwhile, the same process is going on at the opposite brink; and at last a junction is effected midway, and a level track is completed for the passage of the train.

Very frequently, however, the centre of a high embankment is occupied by a bridge, spanning the stream which commonly meanders through our valleys. Where the depressed portion of the ground is very wide and deep, a "viaduct" or series of arches is constructed. Of these arches we shall say little here: works of equal or even greater magnitude had been executed before the rise of the railway system; and we may refer the reader to the "Book of Bridges,"* for information of every kind relative to arched structures of this kind.

The peculiar requirements of a line of railway, however, have given rise to bridges or viaducts of a description entirely novel; and without some notice of these, this little work would be incomplete. The principle of the arch, that is to say, the abutment against each other of wedge-like blocks of stone, termed "voussoirs," has been in many cases entirely abandoned; and in its place the "girder" principle has been very largely adopted. It will be easy to make the wide distinction which separates these two principles clear to our readers.

* Published by the Society for Promoting Christian Knowledge.

Every one is aware that an arch owes its beautiful symmetry of form, and its great strength, to the accurate adjustment, and careful moulding, of the separate component parts. The child, who has played with a toy-bridge built of wooden blocks, well knows that he must support the tiny arch by a mimic scaffolding, until he has dropped in the "keystone," or rather the block which represents it. The actual strength, or power of resistance, of the material employed, does not (except in very large arches) affect practically the stability of the bridge; thus, we may crush or break with ease a single brick, while the union of many such bricks in the form of an arch gives a strength which will sustain any weight which it is possible for us to lay upon it. In very large arches (as we have hinted above), it is requisite to pay attention to the actual strength of the material, because the immense pressure caused by the completed structure might actually crush and splinter the voussoirs, if they were of soft or yielding quality; but it is sufficient for our present purpose to make the general remark, that an arched bridge depends for its stability on the shape and mutual relation of its component parts, and on the capacity of its abutments to resist lateral pressure or thrust, and not on their separate power of resistance.

The girder-bridge, on the other hand, depends entirely on the strength of iron beams, either of solid massiveness, or ingeniously compounded of several parts mechanically connected, and resting with vertical pressure on piers. It is certainly, in principle, less scientific than the arch. To a certain extent, it is a return to the inartificial expedient of a ruder age. The savage, who might wish to cross a rapid stream dryshod, would fell a

tree, and throw it across from bank to bank. Such a tree represents the principle of the girder-bridge, namely, reliance on the inherent strength of the material employed. It is evident that an arch, of any kind, is an immense advance upon the rude log of which we have spoken, and we think we are justified in the remark, that the girder-bridge is, in fact, far behind the arched bridge in the scientific principles of its construction. But we shall have occasion to show that science was perhaps never more conspicuously triumphant, than in the contrivance and erection of some of these girder bridges.

If the reader clearly perceives the difference between the arched-bridge and the girder-bridge, he will see how peculiarly the latter is adapted to the requirements of a railway. The arched-bridge, from its very nature, must always have a considerable height, or "spring," above the level of the water which it crosses. This, though of no importance in some situations, is so important in others as actually to preclude the possibility of using that form of construction. The railway cannot rise to the level of the crown of the arch without an alteration in the levels of the whole line, or a very large portion of it. The crossing of a mere rivulet might necessitate the execution of works involving immense labour and expense, if an arch were the only resource of the engineer. But the girder-bridge, being a perfectly level line, adapts itself readily to any situation in which it may be placed. No one can have travelled by any of our great railways,—especially those which leave London on the northern and eastern sides,—without noticing how the train skims over numerous small streams and broad ditches, within two or three feet of the surface of the water. If arches had been

requisite in these situations, the whole level of the line must have been several feet higher.

Again. In crossing navigable rivers, the girder principle is of immense service. An arch, however bold or noble, must always interfere with navigation. At its centre, it may admit of the tallest vessel passing beneath it without *striking* (both in nautical and landsman's phrase) the top-gallant masts: but it necessarily springs, or commences, from a point at each side comparatively near to the surface of the water. The large vessels are thus confined to mid-stream, and if the piers of the bridge encroach upon the river, the navigable space is still further diminished, or currents are created which may imperil the shipping. The girder—a straight, level beam from bank to bank—is open to no such objections.

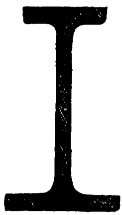
For these reasons, which we have been particular in enumerating, the girder is very frequently preferred to the arch, by railway engineers: and as the girder-bridge is unquestionably a creation, or consequence, of the railway system, we shall here introduce a brief notice of its ordinary forms of construction, with a few particulars respecting the most remarkable of these structures.

We take no notice of iron arched-bridges, because they are identical, in principle, with arches of stone or other material. Of them we will only remark, that hardly seventy years have elapsed since their invention: they paved the way, doubtless, for the use of iron in other forms for the passage of rivers, but they are already almost abandoned,—at least among railway engineers,—in favour of those girder-bridges which we are about to describe.

If *cast*-iron bridges are of recent origin, *wrought-*

iron bridges are of still more recent introduction. The first girders employed, some twenty years ago, by our engineers, were invariably of cast metal: they were, in fact, iron beams, cast in one piece of the length required, and of such depth and form as was calculated to sustain the estimated loads. For short spans, these cast-iron girders served every desired purpose, and within any length not exceeding 40 feet, they are still employed with perfect safety. Their cross section was of the form shown in the margin; viz. a vertical rib, with projecting flanges at the top and bottom.

Fig. 4.



SECTION OF GIRDER.

Encouraged by the successful application of the girder-principle to short spans, our engineers proceeded—too boldly, as the event proved—to employ the same method of conveying the line across wider spaces. The girders, too long to be cast in one piece, were formed of two or more segments, united by powerful bolts and strengthening plates. The compound girder, thus formed, received additional strength, it was thought, from "tension-bars," or "truss-bars," of wrought-iron, so arranged as to sustain part of the load if the cast-iron girder suffered a deflection.

A lamentably fatal proof, however, of the defectiveness of these compound girders was afforded by the failure of the girder-bridge over the Dee, at Chester, on the 24th of May, 1847. This bridge consists of three spans, each 98 feet wide, crossed by three series of cast-iron girders, trussed with wrought-iron bars: each series consisting of four girders, arranged parallel to each other in two pairs, corresponding to the two lines of railway.

Each girder was 109 feet in total length, and was composed of three separate castings, connected together lengthwise by a system of dove-tailed joints and bolts: the castings had an uniform depth of 3 feet 9 inches; the top and bottom flanges were 7½ inches and 24 inches wide respectively; and the average thickness of the iron was 2½ inches. It is needless, here, to enter at length into the reasons why a compound girder of such enormous dimensions is practically weak in proportion to the vast mass of metal contained in it. It must suffice to say, that the strength of cast-iron depends upon its rigidity: whereas the very fact of the addition of wrought-iron tension or truss bars implies the probability of deflection. The reader will easily understand this if he considers that the wrought-iron bars can only come into energetic action *after* the cast-iron has suffered some deflection or bending. Unless, therefore, these trusses were capable of sustaining the whole weight of the girder in the event of a fracture under the pressure of a load, they were practically useless. Moreover, the length, and consequently the tension, of these truss-bars, would be subject to incessant variation from changes of temperature.

All necessity, however, for these reasonings is superseded by the fact that one of these girders gave way under a passing train soon after the completion of the bridge: the carriages were precipitated into the water, and a lamentable loss of human life was the result. The inherent weakness of such compound girders was demonstrated by this unhappy occurrence: the abandonment of the principle followed as a matter of course; and cast-iron girders are no longer employed except for short spans.

Thus foiled in the attempt to combine the effective strength of cast and wrought-iron, our engineers were driven by inexorable necessity to the adoption of some other principle. Solid wrought-iron girders would have been free from many of the defects to which cast-iron girders are subject: but how and where could such girders be forged? It was evident, that some other adaptation of wrought-iron must be devised: nor is it surprising that the idea of using hollow, or tubular, girders, should at last have occurred to the mind of one of our most eminent machinists,—Mr. William Fairbairn.

That strength and lightness are remarkably combined in bodies of a tubular form, must be well known to every reader. The works of the Creator abound with examples of this truth. How wonderful the strength of a common quill! What immense strength is possessed by the hollow bones of our limbs, and of the limbs of the lower animals! The reed and the ear of corn resist many a rude gust, and still maintain an upright position when the storm is over, in consequence of the tubular form of their stems.

To Mr. Fairbairn the honour is certainly due, of first applying this principle, taught by nature, to the construction of beams or girders for bridges and other structures. His plan, (for which he secured a patent in October, 1846,) consisted in the employment of rolled iron plate formed into a rectangular tube with rivets, angle-irons, and other appliances familiar to the mechanical reader. Soon after the date of this patent, Mr. Fairbairn constructed a bridge, supported by tubular girders, over the river Trent at Gainsborough. We have not space for minute details of this structure, and

can only remark that each girder is not less than 154 feet in length, and 12 in depth, made of rolled boiler-plates, rivetted together, and forming a combination of longitudinal cells or tubes. Two of these enormous hollow girders carry the line over each of the two spans into which the bridge is divided; the train rolling forward between the two girders, which form parapets, or hollow iron walls, on each side. The rails are supported on hollow beams, also formed of plate-iron, and laid transversely.

This successful application of the tubular principle to girders must certainly be considered an important event in the annals of railway engineering.

It is no novelty, however, in science or the arts, that the discovery of a new law, or the happy application of a new principle, should be made at the same moment by more than one mind. We may point to the interesting discovery of the new planet Neptune as a remarkable instance of contemporaneous investigation, rewarded by success. And as our countryman, Mr. Adams, is doubtless perfectly content to share the honour of this brilliant discovery with his brother astronomer Mons. Le Verrier, so, we submit, there can be no detraction from Mr. Fairbairn's merit, if we allow that the idea of employing tubular girders for bridges may have occurred to other engineers before the date of his patent. At any rate, it seems clear that the bold project of enlarging the hollow girder so considerably as to allow of the passage of trains *through it*, originated with Mr. Robert Stephenson. As early as the month of May, 1845, he announced to a Committee of the House of Commons his plan for crossing the Menai Straits by hollow girders or

tubes large enough to admit the passage of a train: and though he was most materially assisted in the preliminary experiments, by Mr. Fairbairn and Mr. Hodgkinson, the original scheme was certainly his own. If Mr. Fairbairn was the first to support the roadway upon, or above, tubular girders, Mr. Stephenson was certainly the first to run trains *through* them. It were an ungracious task to investigate now, the exact share taken by each in bringing tubular bridges to perfection; an invention of such importance and magnitude may well be shared between men previously so eminent: and posterity may rightly associate the names of Stephenson and Fairbairn with the magnificent bridge which we are about to describe, and which will remain to the latest generations, a monument of daring design and skilful execution.

The railway from Chester to Holyhead has a peculiar importance as being the nearest route between the sister capitals of London and Dublin. After the legislative union of the two islands, in 1801, the importance of rapid communication between the seats of the Imperial and Vice-regal governments became of great and obvious moment: and between the years 1815 and 1830, the turnpike road from London to Holyhead was improved at great cost, and with consummate skill, by the celebrated Telford, who erected the beautiful suspension-bridge over the Menai Straits, near Bangor, still an object of admiration to all who visit that romantic locality.

This elegant structure, after reigning sole queen among metallic bridges for a period of hardly thirty years, has now been eclipsed by the wonderful Tube to which the rapid advance of science, and the extraordinary demand for facility of com-

munication which characterise the present age, have given birth.

It was essential for the requirements of navigation, that the projected railway should cross the straits at a level of not less than 100 feet above the ordinary high-water mark. This height, or spring, was also to be uniform throughout the whole length of the bridge: and thus Mr. Stephenson's first design of two immense cast-iron arches, was necessarily abandoned; for though the crown of the arches would have been 100 feet above the level of the straits, their springing, or abutments, would only have been 50 feet from the same level. An additional and most formidable difficulty also presented itself in the absolute prohibition, by the Admiralty, of the erection of any scaffolding which should even temporarily interrupt the navigation of the straits.

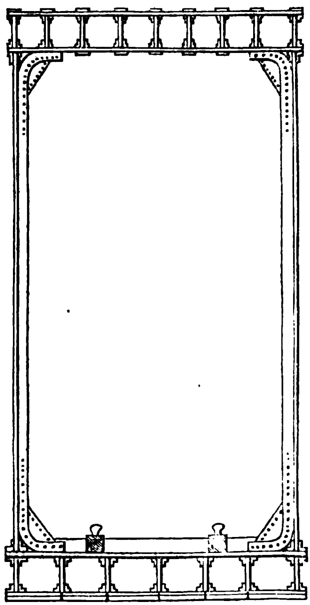
These severe limitations obliged the engineer to strike out for himself a new path in the field of mechanical enterprise. Arches, for the reason stated above, were inapplicable: the suspension principle had been tried at Stockton, and had been found wholly unsuitable and untrustworthy for railway purposes: the girder principle alone remained, and seemed to offer a solution of the difficulty. But the girders, if used at all, must be of enormous and unprecedented dimensions. The distance from each bank to a central rock in the straits, was not less than 460 feet! and across this space, at a giddy height of 100 feet, the girders were to be stretched without the aid of scaffolding.

In the teeth, however, of these appalling difficulties, the engineer set to work. A series of careful and costly experiments, conducted chiefly by

Mr. Fairbairn and Mr. Hodgkinson, proved that a rectangular tube might be constructed of plate-iron, sufficiently strong and rigid to bear any load which could be placed on it without the aid of suspension-chains, truss-rods, or any other auxiliary appendages: and through this tube, as through an aërial tunnel, the trains could pass from one shore to the other without the slightest delay or interruption, and without even the semblance of danger.

Our little work would be extended far beyond its destined limits, were we to attempt to give anything like a sketch of the operations involved in the construction of these gigantic tubes. We must refer the reader, for all details, to the published works on the subject, especially to the little treatise by Mr. Dempsey, published by Mr. Weale, of Holborn, price one shilling. We must content ourselves with a few general statements which may serve to give the reader some idea of these stupendous girders.

Fig. 5.



SECTION OF TUBE, BRITANNIA BRIDGE.

Let him imagine a rectangular (or square-cornered) tube, more than twice as long as

the monument, in London; that is to say, 472 feet in length, *about* 25 feet in average height (being 30 feet in the centre of the entire bridge, and 22 feet 9 inches at the extremities), and about 15 feet in width. Each tube is made of rolled iron plates, riveted at the edges to each other, and to ribs or bars having the form of the letters T and L in their cross section. The top and bottom of each tube is composed of, or strengthened by, longitudinal cells or chambers running the whole length of the tubes.

Let him further imagine a pair of these gigantic tubes laid side by side from the summit of a tower erected on the Caernarvonshire shore to that of another tower situated on the central rock; while a similar pair of tubes extends from this central tower to a third, built on the Anglesey side. Shorter tubes,—viz. 230 feet in length, connect the towers with the embankments on each side; and it will be observed that we have now two lines of tubing, each consisting of four segments, viz. two main spans of 460 feet each, and two land-tubes of 230 feet each. Let each of these tubes or segments be now connected, in imagination, with its neighbour, longitudinally, or end to end; and the result will be two enormous tubes of the length of 1,513 feet each, (including the portions which rest on the towers and abutments,) extending quite across the straits, and appearing to the spectator below, like a light beam stretched from shore to shore.

But let him approach more nearly, and he will be amazed at the prodigious massiveness of the masonry, and the beautiful symmetry of the iron-work. The tubes, as seen in long perspective, present an endless series of rivets, following, in

accurately straight lines, the edges of the plates: while the immense towers convey to the mind an irresistible impression of unshakable stability and eternal duration.

The writer visited this magnificent bridge on the 18th of June, 1851, during the occurrence of a solar eclipse: and he is unable to record in fitting terms, the sensations of astonishment, admiration, and even awe, which the sight awakened in his mind. Seen under the varying effects of light and shade produced by the eclipse, the Tubular Bridge appeared to him to harmonize wonderfully with the scene around: and though he was conscious that he gazed on a work designed and executed by man, he could not but feel that the praise and glory should be ascribed, not to man, but to Him by whom man's mind was given, and man's energies sustained. That majestic structure was but an illustration of the law exemplified in the feather of the bird, in the limb of the horse, in the stem of wheat. Surely it was no fanciful or overstrained feeling of devotion which tempted us to exclaim, as we looked around on the mountains, the woods, the straits, and on the magnificent structure, dimly shown by the eclipsed sun,

"These are Thy glorious works, Parent of good!"

We would gladly extend our notice of this great effort of engineering skill, but a perusal of the little work to which we have referred will put the reader in possession of every important particular relative to the construction of the tubes, their flotation on pontoons or flat-bottomed boats to the foot of the towers, their elevation by hydraulic presses to the dizzy height of 100 feet above the level of the straits, and finally, the ingenious expe-

dient of lowering the ends of the completed tube, by which the stiffness and strength of the whole was increased greatly. We will only now add, that a visit to this most remarkable bridge will well repay the traveller, and will render the construction more clear and intelligible than many pages of explanation.

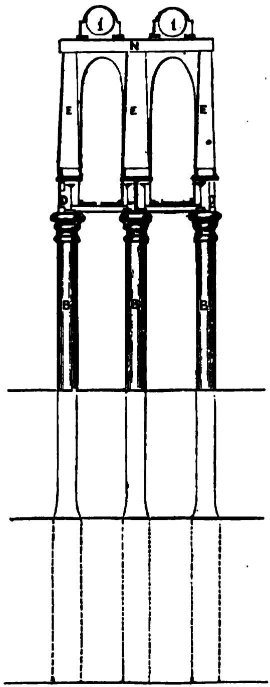
The tubular principle will doubtless be adopted in future, wherever a wide space is to be crossed by a line of railway. A modification of this principle, differing very materially in its details from the Menai Tubular Bridge, has already been applied by Mr. Brunel in the construction of the bridge at Chepstow, carrying the South Wales Railway over the river Wye.

The Wye is a tidal river, navigable for several miles above the town of Chepstow; hence it was necessary, (as in the case of the Britannia Bridge,) that the main stream or channel should not be even temporarily encumbered by the erection of piers or scaffolding, and that a headway of 50 feet above the level of the highest tides should be preserved throughout the whole extent of the bridge. Accordingly, the rails were carried upon wrought-iron girders, resting upon enormous columns of cast-iron, to the extreme margin of the navigable channel; and from this point the opposite shore—300 feet distant—is reached by a very bold and admirable combination of the tubular with the suspension principle.

We have given a general view of the bridge in our Frontispiece. The reader will perceive at once, by a reference to it, that a tower, or standard, (of cast-iron,) is erected upon the columns which stand in the bed of the river, and that a similar tower, or standard, (of masonry,) is placed on the

opposite shore. Two tubes of wrought-iron, 312 feet in length, and 9 feet in diameter, are laid, parallel to one another, upon the summits of these towers, at a height of 100 above the level of high-water. In the accompanying cut, B B B are the columns, E E E the cast-iron tower, N a wrought-iron girder, carrying the ends of the tubes I I.

Fig. 6.



It is evident that we have described, thus far, a structure similar in its main features to that of the Britannia Bridge; namely, wrought-iron tubes resting, with vertical pressure, on piers. But here the resemblance ceases. Mr. Brunel has not carried the roadway through the tubes, but has suspended it beneath them by chains attached to the ends of the tubes, and passing under saddles formed on the edges of the wooden platform which bears the rails. To prevent oscillation, he has introduced vertical and diagonal braces between the tubes and the roadway, and by means of adjusting screws, the chains can be pulled or stretched to such a degree of tension that they possess, in fact, all the rigidity of actual girders.

The function of the tubes, in fact, is to furnish

two fixed and uniformly distant points of attachment for the suspending chains, and to change their lateral pressure or tension into a vertical pressure upon the piers.

The numerous beautiful contrivances for effecting the complete adjustment of all the parts, and for counteracting the danger of unequal expansion, well deserve a more detailed description. The whole structure is a noble example of mechanical and constructive skill; and the reader will probably agree with us, that if it yields to its great northern rival in simplicity, and in colossal grandeur, it is nevertheless, from the lightness and elegance of its form, in admirable harmony with the picturesque scenery of the river Wye.

Ere we close this chapter, we offer the reader a brief recapitulation of its contents. We have shown, or tried to show, the preliminary difficulties which must be overcome in determining the line of route; we have glanced at the method of forming a tunnel, and at the simultaneous construction of a cutting and an embankment; finally we have shown how the passage of wide chasms is effected by girder-bridges—the offspring of the railway system. We pass on to consider in the following chapters, the arrangements requisite for the transport of passengers and goods; the methods employed for forming and securing to the ground the rails themselves; the construction of the engines and vehicles which traverse them; the stations, with their numerous appliances for the promotion of safety, comfort, and despatch.

CHAPTER III.

THE PERMANENT WAY.

It is probable, that long before the completion of the heavier works requisite on a Main or Trunk Line of railway, a greater or less amount of traffic has been carried on upon detached portions.

Many of our readers doubtless remember the inconvenience to which the public were unavoidably subjected, during the construction of these great arteries. The traveller, ensconced in a comfortable first-class carriage, was awakened from his slumbers by the unwelcome intelligence, that he had arrived at the temporary terminus of the railway. Reluctantly leaving his snug berth, he finds himself surrounded by the waggons, barrows, timbers, sheds, and all the other apparatus used in forcing a passage through the hill, which forbade his further progress. A dozen coaches appear in the background, and while he stands shivering upon the muddy ground, the trunks, portmanteaus, bags, boxes, bundles, and indescribable et ceteras of the passengers are arranged upon these vehicles, which drive off one by one,—a striking contrast to the rapid and commodious carriages, for which they are a temporary substitute. Any one who may have travelled to Bristol before the completion of the Box Tunnel, or to Cambridge, or Southampton, or Birmingham, before their respective lines of railway were extended to those places, will not deem this picture overdrawn.

It will facilitate, however, our description of the

"Permanent Way," if we simply view it as laid down along the whole line of route; as it appears in short, when all is complete, and when the narrow strips of metal are continuous through tunnel and cutting, over embankment and bridge, from one terminus to the other.

It is most interesting to observe, how the success of one invention depends upon that of another, or of many others. The Steam Engine, or the Power Loom, would never have reached their present perfection, but for the beautiful machines by which their component parts are shaped, polished, and adjusted; and thus, if it had not been for the invention of the Rolling Mill, the railway system must have been materially retarded in its advance.

The rolling mill, the invention of a Mr. Henry Cort, about the year 1783, consists of two ponderous iron rollers, arranged one above the other in a massive frame, also of iron, and revolving rapidly by the power of steam, water, or some other adequate prime mover. The rollers can be adjusted at any desired distance from one another, and if we now suppose a bar of iron, heated to a white heat, to be passed between them, the pressure will flatten the two surfaces in contact with the rollers, and will have, at the same time, the effect of elongating the bar.

But, if grooves have been previously turned on the surfaces of the rollers, the bar, instead of being flattened merely, will be moulded into the form of the grooves through which it is passed. Thus, if a semi-circular groove be turned in each roller, the product will be a round rod. And by using grooves of gradually diminishing depth and size, we reduce a massive bar of iron, two or three feet long, and several inches in diameter, to the form of a slender

rod, many yards in length, and resembling a fiery serpent, as it twists and writhes upon the floor of the mill.

It is now perfectly easy to conceive, that by varying the shapes of the grooves, as well as their sizes, we can obtain bars of any simple form which may be desired.

This beautiful invention had been patented for many years before it was applied to the manufacture of railway bars. The first edge-rails, we have already stated, were of cast-iron, but the brittleness of this material was a constant source of danger and expense. It was necessary to form the cast-iron rails in short lengths, and of great massiveness or proportionate weight; though we should state here, that the immense traffic of the present day has led to the introduction of rails of a weight, per yard, vastly greater than any which were employed in the earlier railways.

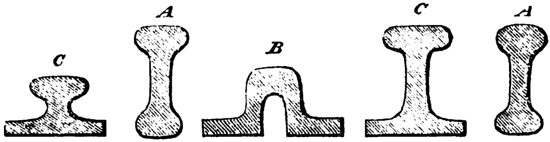
The idea of using wrought-iron rails, formed in the rolling mill, appears to have occurred about the year 1820, to a Mr. Birkenshaw, an iron-master in the county of Durham. His method of forming rails is in use at the present day, and even the shape or section, suggested by him, is still generally adopted. The only important change is, as we have hinted above, the vast increase in the weight of the rails per yard. Thus, the wrought-iron rails first used on the Liverpool and Manchester Railway, weighed 35 lbs. per yard: the weight of those now in ordinary use varies from 44 to 84 lbs. per yard.

We have given in the accompanying figures, a few of the forms of cross section most approved.

The rails, formed in the rolling mill to the shape or cross section required, and in lengths of from 15 to 24 feet, are arranged, it is almost unnecessary

to say, in two parallel double lines. On each of these lines, the traffic flows in one direction only;

Fig. 7.



CROSS SECTION OF RAILS.

that is to say, if one line is traversed by trains going "up," the other is confined to those going "down." The old rule of the road is maintained on the railway, by every driver keeping the left-hand line; thus, he meets and passes all other trains on his right-hand side; and, except in case of urgent necessity, and under special precautions, he is rigorously interdicted from proceeding "upwards" on the down line, or *vice versâ.* But this is in anticipation of a subsequent page. Two double lines of railway, at any rate, are to be provided for the accomodation of the up and down traffic; and these double lines are to be furnished with short connecting lines, with sidings, or extra lines at stations; with switches or points, for transferring carriages from one line to the other; and with turn-tables for reversing the position of engines and other vehicles.

Now, it will be evident, that the two continuous tracks of iron which form one "line," must be laid strictly parallel, or at an uniform distance apart, from end to end, otherwise the same carriage could not perform the whole journey. But it was not so evident to the earlier projectors of railways that this uniform distance between the rails, technically

called their "guage," should be the same in *all* great arterial lines. They could hardly have anticipated the immense extension of the railway system, which has since taken place. They could not have been expected to foresee the extreme repugnance manifested by the travelling public to a "change of coaches," or the vast inconvenience, and even loss from serious damage, incurred by a transfer of merchandise, from one set of waggons to another. It is not surprising, therefore, that uniformity of guage was not among the desiderata sought by the early engineers of our trunk lines.

We have before remarked upon the principle of non-interference, which seems to be one of the chief guiding motives which actuate the British government, in its dealings with commercial enterprise; and however healthy may be the general working of this un-meddling system, it has certainly, in the instance before us, been productive of serious inconvenience. An authoritative decision of the guage question, at a period when the railway system was in its infancy, would have prevented much costly litigation, many unseemly disputes, and much interruption of communication; but, as we before remarked, the difficulty was not foreseen, and the interests involved are now of such magnitude, that the evil must be considered incurable.

It would appear that mere accident led to the adoption of what is now called "the narrow guage." The best colliery railways had a guage of 4 feet 8½ inches; and this guage was used on the Stockton and Darlington line, which was connected at many points with the depôts of coal-pits. The Liverpool and Manchester, the London and Birmingham, the Midland Counties, and other great companies appear to have adopted this guage

rather by chance, than in any well-considered expectation of mutual convenience; but the amalgamation of some of these companies, and the close connexion of others, has given to this guage an importance which was by no means foreseen, and to which no inherent excellence entitles it.

A guage of 5 feet was adopted by the Eastern Counties and Blackwall lines, though the former has since been altered to the narrower guage: and guages of 5 feet 6 inches, and of 6 feet 2 inches have been used in certain railways of Scotland and Ireland.

Passing by these, however, as of minor importance, we proceed to remark that the "broad guage" of 7 feet was introduced by Mr. Brunel, the engineer of the Great Western Railway, and has been used on all lines dependent on, and tributary to that great artery of communication. At every point, therefore, where these very different guages meet, a change of carriages and transfer of merchandise is necessary.

The evils of the "Break of Guage" are obvious: it is less easy, and might be deemed presumptuous, to decide between the conflicting claims of the two guages to superiority. We have said, however, that no peculiar or magic excellence resides in the exact measurement of 4 feet 8½ inches: while one decided inconvenience attends it, viz. that the carriages, in order to accommodate the usual number of passengers, must be made to overhang the wheels on each side, thus certainly increasing, to some extent, the danger of oversetting. On the broad guage of 7 feet, the bodies of the carriages are hung between the wheels, which may thus be made of a much larger size; and, the centre of gravity being greatly lowered, a much higher

speed may be safely attained. Accordingly, sixty miles an hour,—the speed of the famed racer "Eclipse,"—is a rate of travelling daily attained by the express trains on the Great Western Railway. At the same time, it is said that the consumption of fuel in the immense engines, rendered necessary by this high speed, and the wear and tear of the line, caused by their great weight, lead to a considerable proportionate increase in the working expenses.

May it not be fairly allowed, that perhaps a medium guage of 6 feet would have secured all the advantages, without being attended with any of the evils, of either system?

It is vain, however, to hope that a new guage can now be adopted: and equally vain to expect that either of the great rival parties will alter their guage to that of the other. At the same time, we must point out, that if any change of this kind were contemplated, it might be gradually effected at a comparatively moderate expense, by laying narrow-guage lines between those of the broad guage. Mixed trains might then be run upon the line, consisting of both broad-guage and narrow-guage carriages.

Leaving this much-vexed question, however, we have now to point out the manner in which the rails, whatever their guage, are secured to the ground.

The whole line having been brought to "formation level," as it is called; that is, to the proper levels and inclines throughout, a "ballasting," or coat of clean gravel, broken stones, burnt clay, or other material not affected by wet, is laid upon it. On this ballasting, the sleepers are deposited which are to bear the rails. Of these sleepers, we may

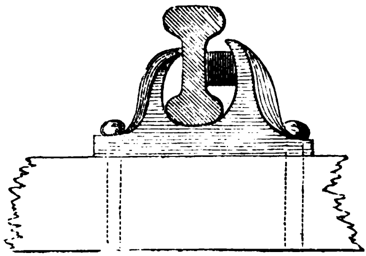
remark, that they are now uniformly of wood. Stone blocks were largely employed in the construction of the great lines first laid down: but their unyielding rigidity was very apt to cause a loosening of the pins which connected the rails to them, as well as communicating an unpleasant, harsh "jar" to the train. These stone sleepers, therefore, have been almost entirely superseded by wooden ones: but these latter are applied in two separate ways. Agreeably to the first method of employing them, they are laid transversely, or at right angles to the line of rail. They are commonly made from logs of larch or fir, sawn longitudinally in half, so that each log forms two sleepers. Mr. Cubitt, however, has employed sleepers formed by sawing a square log of Baltic timber *twice diagonally;* each log thus supplying four sleepers of triangular section. In any case, these wooden sleepers are exposed to a peculiar process, called "Kyanizing;" which consists in impregnating them thoroughly with a solution of corrosive sublimate, after which they are capable of resisting the effects of damp, and of continuing sound in the most exposed situations.

The sleepers, so prepared, are laid upon the ballasting, which has been well rammed and levelled for their reception, at intervals of from 3 to 4 feet. On each sleeper, of course at an accurately measured distance apart, is firmly secured a cast-iron "chair," or pedestal, the form of which will be best understood by an inspection of the accompanying figure; and to these chairs the rails are connected by wooden wedges, which force the projecting flange, or rib, of the rail into a cavity left in the chair.

This mode of connecting the rails to cross sleepers is the one adopted on most of the great narrow-

guage lines of this country: but the other mode, first introduced by Mr. Brunel, has been regarded with great favour, and is likely to supersede, ulti-

Fig. 8.



RAIL AND CHAIR.

mately, the older method. It consists in laying the rails on longitudinal timbers, which repose on the ballasting, and which are retained at their proper distance apart by cross pieces. The rail is thus supported at every point in its length; and the form of rail called the "bridge-rail" (see the figures on a former page) is adopted as most suitable to this form of construction. No chairs are required, the rail being screwed to the bearing timber at short intervals, a layer of felt being interposed between them. This continuous bearing has been adopted on several other lines besides the Great Western;—on the London and Croydon, for instance, a species of rail known as the "foot-rail," (No. 1 in the figure at a former page,) is supported on longitudinal sleepers resting on transverse timbers.

We pass over several ingenious modifications of these two methods, because, though possessing much merit, they have failed in obtaining the approval of practical engineers. Probably some of

them may be found of value in situations where circumstances preclude the adoption of the ordinary modes of construction.

We must not omit to notice, however, one very ingenious and scientific arrangement in the laying of the Permanent Way.

All our readers must have noticed, that a body or mass of matter, when traversing a curve, has a tendency to diverge, or depart from the centre of that imaginary circle, of which the curve is an arc or segment. In the feats of the circus, the horse and rider counteract this tendency by inclining greatly from the perpendicular as they move round the ring: and the more the pace is accelerated, the more visible does this inclination become. At last, when the well-trained creature is urged to his utmost speed, he assumes a position with respect to the level earth, which he could not maintain in a state of rest, without falling. In a similar manner, the skater inclines his body from the perpendicular as he executes those curves and figures which are so striking a feature in his graceful and bèautiful exercise. In both these cases, the leaning is quite involuntary, or, as we call it, "natural;" the impulse of the horse and man prompt both to throw the body into such a position that its balance may be preserved.

Now, a very slight acquaintance with the laws of mechanics is sufficient to teach us, that bodies revolving round a centre acquire a force called a centrifugal force, which tends to drive them (as the term implies) from that centre, and to impel them forward in a straight line with more or less violence. A sling and stone is a familiar instance of this. A train, rapidly impelled round a curve in the line, is, in fact, a body revolving partly round a centre, and

of course comes under the operation of the centrifugal force, which tends to throw the carriages off the rails, and to hurl them forward in a straight line.

The engineer counteracts this dangerous tendency by the same simple means which nature suggests to the circus-horse and the skater, viz. by making the carriages lean or incline towards the imaginary centre of the radius. He raises the outer rail above the level of the inner: the amount of this raising, or (as it is termed,) super-elevation, being, of course, mathematically proportioned to the radius of the curve, the guage of the line, and the proposed velocity of the trains.

We dare say many of our readers little suspect how much their safety, while travelling, depends upon this and similar beautiful contrivances: we shall rejoice if we have succeeded in awakening their attention to matters of detail, which, from their apparent simplicity and unobtrusiveness, are apt to be passed by, unnoticed. A complicated and beautiful piece of mechanism attracts our gaze at once: but the most intricate machinery should scarcely rouse our admiration more strongly than that skilful union of theory with practice,—of the mathematical formula with the accurate construction,—which enables us to traverse a curve, at express speed, with perfect safety!

These mathematical adjustments of the rails are not the only matters which require the careful superintendence of the engineer. The arrangement of the "switches," or "points," especially in positions where several lines meet, is a matter of very great importance, as the most frightful consequences might ensue, and in one or two instances have ensued, from the failure, at a critical moment, of these contrivances.

The switch consists of a short rail which revolves on a pin or centre at one end, and at the other can be made to lie closely in contact with the inside of one of the main lines of rail, or to retire a few inches from it. The switch itself is merely a continuation of a line of railway which diverges from the main line, making with it a very small angle; and which becomes connected, by a similar switch at the other end, with the parallel line of rails, or with a branch line, or with a siding. We have figured one of the simplest forms of the switch; its operation will be understood at once by inspection; and it is, indeed, probably already familiar to the reader. We fancy, however, that the object of the short rail, slightly bent, which is invariably fixed opposite to the points, and near to the inner side of the other rail, is much less generally understood.

Fig. 9.

SWITCHES AND POINTS.

Now, it must be observed, that the guage of the carriage-wheels is perceptibly less than that of the rails, so that a certain amount of "play" is allowed to them in traversing the line. It need hardly be remarked, that they are retained upon the rails merely by the flanges or ribs upon their inner peripheries. If, then, in approaching a switch, the flange of the wheel were either too near to the rail, or too far from it, it might, on the one hand, fail to catch the point of the switch; or, on the other, might catch the point when not intended to do so.

In either of these cases, fatal consequences might ensue. The short, bent rail, called a guide-rail, removes this danger. By acting on the flange of the opposite wheel, it draws the carriage over into the position most favourable for catching the points with unerring precision. These guide-rails will be observed wherever two lines of railway intersect each other, giving rise to the necessity of cutting or dividing the rail. We have shown two in our figure.

The present appears the proper place for noticing the remarkable phenomena in connexion with the rusting, or oxydation, of rolled malleable iron railway bars. It is observed that the rails, when fixed in their position and daily traversed by trains, are wholly free from rust, not only on their upper surface, where its absence would easily be accounted for by the friction of the wheels, but also on their sides: while a loose bar of the very same iron, laid on the ground, is perpetually throwing off scales of rust. This most singular fact seems to denote the operation of some magnetic or other influence which destroys the chemical affinity of the iron for the oxygen, or carbonic acid, of the atmosphere. If this influence—whatever it be—is brought into play by the attrition of the passing wheels, our astonishment is changed into gratitude for the provision of Nature by which the very cause which tends to wear out the rails, tends also to counteract the wasting effects of rust. So true it is, that in the most artificial contrivances of man's ingenuity, some simple natural law may invariably be traced as the main-spring and first cause of those results which we are apt to ascribe to the mere combinations of matter.

CHAPTER IV.

THE TRAINS.

A VERY few years ago, a railway train was an object of wonder to all who witnessed its rapid transit. The ploughman left his team, the smith his forge, the housewife her churn, to gaze at the novel sight; and after following it with their eyes to the utmost limits of vision, turned slowly away with some expression of wonder,—almost of awe. The familiarity of the spectacle has now deprived it of its attractiveness in the eyes of the uneducated: but we think no reflecting person can even now witness the passage of a train without a feeling of astonishment. Let him stand near the margin of the line when an "Express Train" passes him at full speed. How mysteriously it appears to quicken its velocity as it approaches us! How it appears to progress almost by leaps, or bounds! How, at last, it rushes by, with a deafening noise, and with an agitation of the very ground we stand upon! We have hardly time to count the carriages, ere it is gone, leaving behind it no trace of its flight, save a cloud of dust, and perhaps a few red-hot cinders whirled from the furnace of the engine. Or let him view another sight, equally or still more astonishing: we mean the comparatively slow passage of a heavy train of "Goods," as the luggage waggon-trains

are technically termed. Not unfrequently two ponderous engines are yoked together to a train of from 80 to 100 waggons, loaded with every kind of merchandise. Closed vans, filled with delicate silks or velvets; open trucks, groaning under the weight of iron girders, or enormous boilers, or massive machinery; waggons filled with slates from Wales, or broad flag-stones from Yorkshire; timber-trucks laden with balks of pine from the Baltic,—these are but a few of the component parts of such a train. Add to these the vans or carriages crowded with bullocks; the pens of sheep or pigs;—(horses, as more aristocratic animals, are allowed to travel by the same trains as their masters;)—a few loads of coke for some road-side dépôt; and perhaps a "cold" engine, drawn along to its place of repair,—looking like a giant in leading-strings,—and we have an idea of the miscellaneous collection of valuable property conveyed by one of these trains. The rear is invariably brought up by a "break-van," heavily laden with weights for the purpose of giving efficacy to its apparatus for retarding or stopping the train: but long ere this passes us, the engines are far away down the line, and their heavy panting is fast becoming inaudible.

To us, this is one of the most remarkable sights connected with a railway. The idea of enormous power held in perfect control, is conveyed to the mind so forcibly by no other spectacle. Even the steam-vessel appears to us to yield to this in the impression made upon the beholder. And when we analyse this impression, we find it is justified by the astonishing variety of the contrivances brought together in such a train. It is bewildering to think of the number of wheels, axles, springs,

breaks, and chains, which must each fulfil their destined office to ensure the safety of the moving line of waggons. The massiveness and weight of the bodies in motion must not distract our attention from the extreme and minute accuracy observable in all the constructive details. The working parts of the engines are finished and fitted with a nicety unsurpassed by the watch-maker. Every wheel, every axle, has been turned to its true figure in the lathe. But of these particulars we shall have more to say;—we have said enough, perhaps, to induce our readers to gaze at a passing train with something more than a mere vacant stare.

We shall speak first, in the present chapter, of the rise and progress of that wonderful contrivance,—the Locomotive Steam-Engine, now almost universally employed as the tractive power on our Railways. We say *almost* universally employed: for it will be necessary to notice, briefly, one or two other modes of traction which have found a partial acceptance.

The Locomotive Engine, like the road which it traverses, is the result of the combined theoretical and practical skill of many eminent mechanists, and cannot be fairly claimed as the invention of any individual. The illustrious WATT, indeed, contemplated the application of steam to the propulsion of wheel carriages, and threw out some hints as to the mode by which this could be effected: but the same *idea*, in a vague and visionary form, seems to have been previously entertained by other eminent men.

It is due, however, to the memory of an engineer whose name has been too much overlooked amid the dazzling achievements of modern times, to state that Richard Trevithick, of Camborne, in Cornwall,

with the aid of his partner Andrew Vivian, seems to have been the first who practically applied the power of steam to the propulsion of wheeled carriages. In a patent, taken out in the year 1802, they describe the construction of a remarkably simple and beautiful steam-engine, specially adapted for propelling vehicles on common roads, —for the use of railways had as yet by no means become so general as to engage the primary attention of engineers. Several of these vehicles were constructed in the years 1803 and 1804; and in the latter year one of them was tried upon a Welsh tram-road, with a result entirely satisfactory.

If any name, therefore, deserves to be connected with the first introduction of steam locomotion, it is the name of TREVITHICK: and it is peculiarly noticeable, that that intelligent machinist seems to have risen superior to a common prejudice which was not rooted out until long after his time, and which caused the needless expenditure of much time, trouble, and money by many subsequent inventors. This prejudice was, that the mere friction, or adhesion between the wheels and the road, is not sufficient to propel the carriage.—A few remarks may facilitate the reader's conception of this imaginary difficulty.

A carriage drawn by horses owes its progress to the muscular power and weight of the animals, exerted by the pressure of their feet against the ground. That is to say, the whole tractive power of the horses is dependent on the friction, or firm hold, of their feet upon the road. Diminish this friction, and you diminish their power. Every one has witnessed the painful scenes presented when the surface of a steep hill, or of the wooden pavement in our great towns, is glazed by frost. The

poor horses are then unable to exert any tractive force; and it is necessary to "sharpen" or "turn up" their shoes in order to give their feet a hold on the slippery road. It is evident that the friction of the horses' feet must be distinguished carefully from that of the wheels of the carriage drawn by them. The same cause which diminishes the power of the horses, increases the facility with which the carriage rolls on: and this facility reaches its maximum when the frozen surface of a lake is traversed by sledges,

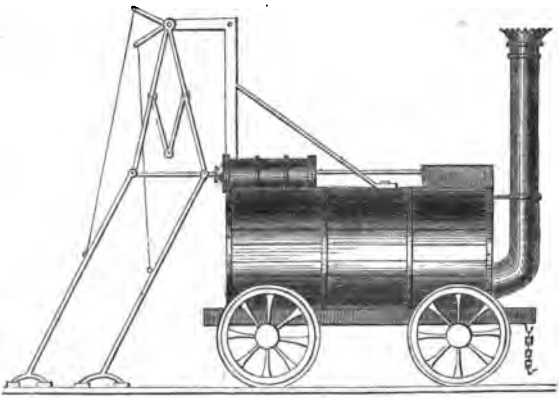
Now, an engine, drawing a train, is in a position strictly analogous to that of a horse yoked to a carriage or waggon. The wheels of the engine represent the feet of the horse. The internal power, applied to turn these wheels round, is a faint and humble imitation of that vital principle which actuates the sinews and muscles of the noble horse. Take off (in imagination) the tires or rims of the wheels, and you have a pretty close resemblance to a series of legs in the spokes which remain. Each spoke may represent a leg: and in its turn, it is evident, will be thrust or pushed against the ground as its abutment. Arm these spokes with feet, and connect the feet into the circular form of a tire, and we again have a wheel. This wheel propelled from within, owes its forward motion entirely to friction. The horse, placed with smooth shoes on ice, cannot draw his load: he moves his feet, but they slip from under him, without advancing the carriage. In a manner precisely similar, the engine-wheel, (if friction were reduced to nil,) would be forced round by the motive power, but it would slip upon the surface beneath it, without having the slightest effect upon the load. Consequently, the rolling friction of the

engine-wheels must be entirely distinguished from the rolling friction of the carriage-wheels drawn by the engine It is clear that what we gain by diminishing the friction of the train, we lose by abridging the power of the engine; while, on the other hand, just as by sharpening our horses' shoes we enable them to draw sleighs on ice with astonishing ease, so, by increasing the friction between the engine-wheel and the rail, we give increased tractive power to the engine itself.

The error into which early projectors were led, was that of imagining that the friction between a smooth iron tire and a turnpike road,—(*à fortiori*, between the same tire and an iron rail,)—would be at all times too slight to ensure an available tractive power. They imagined their mechanical horses must always be sharpened. Consequently, they wearied themselves in devising expedients for increasing the friction between their engines and the road. One very ingenious machine—the invention of Mr. Brunton—was provided with actual legs of iron, terminating in feet armed with short spikes, which took hold of the road. These legs had a step, or stride, of about 26 inches, and were made to abut alternately against the ground by the reciprocating action of a steam piston and cylinder. The ludicrous appearance which this ingenious engine must have produced, (for it was actually set to work, and performed satisfactorily,) can hardly be exaggerated. To have seen the nondescript offspring of steam and iron stalking along its path, would surely have been a sight "passing strange." We suppose instead of the usual order "Go ahead!" the command to the driver would have been, "Come! step out! put your best leg forward!"

These "legs" found many imitators, among them, Mr. Goldsworthy Gurney, whose attainments

Fig. 10.



BRUNTON'S "MECHANICAL TRAVELLER."

in other branches of science need no encomium from us, but whose share in the "invention" of locomotive engines has been over estimated. His first carriages, patented in 1825, are encumbered with propellers, or legs, acting upon the road. A moment's consideration must show the uselessness of these. We have pointed out the close and intimate resemblance between the steam-impelled wheel, and the foot of the horse. The wheel is, in fact, a continuous foot. Now, these propellers could only act upon one point in the road at each application of the power,—the propeller remaining fixed until the carriage rolled on to the limit of its action or play: whereas, in the action of the wheel, though the actual point of abutment of the power against

the ground may be conceived to remain fixed during an inappreciable interval, the power is in fact applied to an infinitesimal number of such points successively,—*every* portion of the track, and not certain detached portions, or foot-prints only, being subjected to its action. Mr. Gurney, therefore, substituted, for a mode of propulsion which he deemed insufficient, another mode much less effective! On slippery roads, his propellers would of course slip like the feet of horses; and if sharpened or armed with spikes, would dig up the road; while in this latter case (as we have shown above) the effect would have been much more easily produced by roughening the tires of the wheels.

We have said that Mr. Trevithick was never deceived by this imaginary difficulty: in his specification of 1802, he expressly says that "the ordinary structure or figure of the external surface of the wheels will be found, in general, to answer the intended purpose" of propelling the carriage. At the same time he hints at the possibility of using contrivances for roughening the tires of the wheels "*in cases of hard pull.*"

The reader will perceive that our remarks upon Mr. Gurney's propellers have reference to their use on common roads. On railways,—though we shall show that even there they are quite useless,—there is much more show of reason for their adoption. For if the propeller can act upon a rough surface between the rails, while the wheels run upon the smooth metal, it is clear we have achieved a desideratum by giving a maximum amount of adhesion to the propelling power, while a minimum is allotted to the bodies propelled. Accordingly, though experience has shown the sufficiency of the simple friction between the wheel and rail for all ordinary purposes,

it is not surprising that several clever contrivances were patented for attaining the object we have mentioned. The chief of these consisted in a toothed rack, or series of cogs extending along the line of railway. A toothed wheel, worked by the steam-engine, was engaged by this rack, while the wheels and train moved over smooth rails. Thus a fixed abutment was obtained for the power: and the supposed difficulty was overcome. Another projector devised a middle rail, pinched or nipped between rollers, worked by the engine. But all these contrivances have been forgotten, together with the imaginary difficulty which gave them birth: and we refer to them here only as a proof how singularly men of science sometimes refuse to be guided by the experience of others, and in the blind pursuit of some favourite theory, waste the time and energy which might have advanced the cause in which they were interested. Trevithick showed, in 1803, that the mere adhesion of the wheels was sufficient to propel a carriage on common roads: yet in 1825, Mr. Gurney is patenting "propellers!" But "the history of failures shortens the road to success;" and the labours of these ingenious men doubtless paved the way for the introduction of those magnificent engines which are now seen drawing after them immense loads, at a speed unimagined in the wildest dreams of Mr. Brunton's "Mechanical Traveller," (if he dreamt after his walks,) by the mere rolling friction of a smooth wheel against a smooth rail. Even now, however, Trevithick's proposal of *occasionally* using additional means for increasing friction, is acted on by providing engines with boxes from which sand may be scattered on the rails in ascending inclines, or when the rails at some par-

ticular point are peculiarly slippery. This eminent man's plans, therefore, may be fairly considered as forming the basis of our present system of locomotion.

We have said, that in the first instance the propulsion of carriages on common roads was the principal object of the projectors of locomotive engines. But we may take leave here, of these ingenious, but abortive schemes;—abortive, from no want of clever adaptation or mechanical resource, but from the insuperable obstacles presented by the unavoidably rough surface of our roads when newly repaired. A common-road steam-engine can contend successfully with every obstacle save that which must occasionally be encountered,—the obstacle presented by a coating of rough broken stones. The jolting caused by these, soon loosens the joints and disarranges the parts on which the working of the delicate steam apparatus depends. It is evident, also, from what has already been said, that as we improve the roads, we diminish the adhesion of the wheels to its surface, and therefore the power of the carriage to surmount eminences: while, if we are to cut down the hills to make a level track for the carriage, we may as well at once construct a railway. We are far from saying that common road locomotion on a limited scale—for instance, to and from railway stations,—may not at a future day, possibly, be brought into practical application: but experience confirms theory in establishing the fact that steam cannot be brought into successful pecuniary competition with horses on common roads.

We take our leave here, then, of the Common Road Locomotive; and proceed to notice the gradual advance to its present perfection of its powerful rival, the Railway Engine.

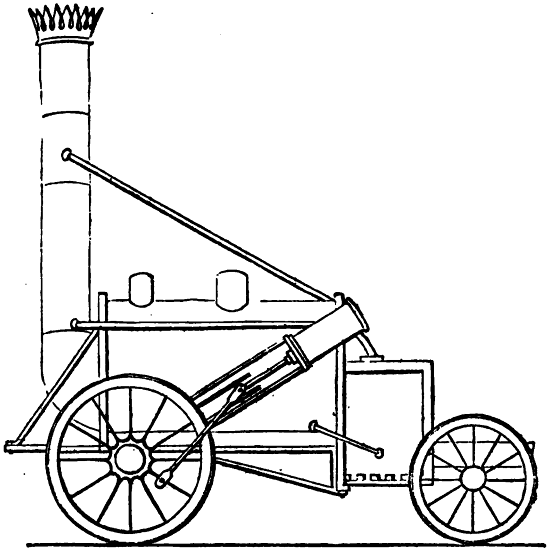
It was reserved for the Liverpool and Manchester Railway Company to make the first great experiment in the practical working of locomotive engines in daily rapid traffic. The scientific world, and, indeed, the general public, owe much to that enterprising Company, who, at great cost to themselves, established many fundamental laws which have since been unhesitatingly followed by the engineers of subsequent undertakings.

During the construction of the line, it became a subject of anxious consideration among the directors, what tractive power should be employed to convey the traffic. After much consultation with the most eminent scientific men, it was resolved to prefer locomotive to fixed engines, if they could be made to fulfil certain conditions as to weight, power, and cost. A reward was offered in April, 1829, for the best locomotive engine capable of drawing three times its own weight at ten miles an hour:—in weight not to exceed six tons when filled with water; and at a cost of not more than 550*l.* These stipulations appear extremely moderate when placed side by side with the results achieved by twenty years' experience. Now we daily see engines which weigh (with their tenders) 30 tons, drawing immense loads at speeds varying from 20 to 60 miles per hour, and costing 2,200*l.* each! But we must recollect that in 1829 railways and locomotion were yet in their infancy. Their growth has indeed been precocious!

Four locomotives were entered for competition, in accordance with this invitation on the part of the directors: and it must suffice to add, that the "Rocket" engine, constructed by Mr. Robert Stephenson, was declared by the judges to have fairly won the prize of 500*l.*

Unless great injustice is done to the "Rocket" by the artist, there was little to admire in the

Fig. 11.



THE "ROCKET."

construction. The accompanying sketch may give an idea of the proportions. It will be observed that the cylinders of the steam-engines are placed diagonally, and act directly on a pin attached to the spokes of the wheels. In one of the rival engines, the "Sans Pareil," the cylinders were placed vertically above the wheels driven by them.

The author observed an extremely antiquated engine drawing ballast wagons near the town of

Stockton-upon-Tees, during the summer of 1853. This uncouth specimen of early locomotion had vertical cylinders, like the Sans Pareil; and (as in that engine) the furnace was fed in front, the flue being returned or bent within the boiler, so that both chimney and furnace-door were at the same end. On questioning the driver, (whose exterior corresponded with that of his engine, and whose mouth was adorned with a short pipe, save when he opened it to answer very civilly our inquiries,) we found that the speed of this ancient machine was six miles an hour. "You might get nine out of her," the man said,—but we thought to ourselves we would not willingly have pressed the old engine to such unseemly haste. It was a curious link between the past and present: and when the passenger engine which was to draw our train dashed up, all bright and clean, its brass-work glittering in the sun, its very appearance betokening healthy and vigorous activity, we fancied the ancient machine wheezed out a kind of grunt, such as a choleric old man might vent as he slowly turned to look after some gay young spark, "got up" in the height of the fashion.

"Crabbed age and youth cannot live together,"

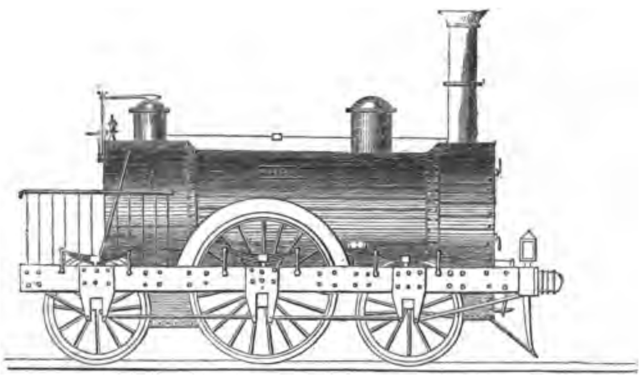
we thought, as our smart locomotive whirled us away, while still gazing with a kind of fascination on the old engine.

The success of the "Rocket," and of the engines turned out on the same model by her constructor, established beyond all doubt the complete sufficiency of the friction between the wheels and rail for all purposes of ordinary traffic. Moreover, the speed and power of the engines astonished even those whose conviction of their success had been

most sanguine. Ten miles an hour had been fixed as the limit of speed, and had been pronounced by Mr. Tredgold, a very competent and unprejudiced authority, as the highest speed attainable, under ordinary circumstances, with safety. Yet the journey from Manchester to Liverpool (thirty-one miles) was performed in one hour, within a very few months after the opening of the railway! and at the present day, the Great Western express performs its first stage, from London to Didcot, (fifty-three miles) in the same number of minutes! and this in all weathers,—frequently in the teeth of a furious westerly gale!

The improvements in locomotives, which have led to this astonishing victory over time and space,

Fig. 12.



MODERN LOCOMOTIVE ENGINE.

have been numerous, but gradual. The reader will best understand their nature and extent, if we present him with a drawing and description of one

of the magnificent engines of the present day. He may compare or contrast the drawing of this modern marvel, with that of the "Rocket,"—its progenitor.

It is not the province of this little work to enter into minute details respecting the construction of Locomotive Engines: these may be found in any of the elementary works on the Steam Engine which are now accessible to all readers. We shall pass over, without notice, the cylinders, pistons, valves, and other apparatus common to all steam-engines, fixed or movable; and shall merely call attention to those points which peculiarly distinguish the modern Railway Locomotive from those which have preceded it.

By an inspection of the figure, it will be seen that the engine is mounted on 6 wheels. These wheels do not revolve independently on their axles, as in common road vehicles, but are secured immovably, in pairs, upon shafts or axles which support the weight of the boiler and engines on brass bearings. Of these 3 pairs of wheels the centre pair only is "driven" or actuated by the power of the steam-engines: and it is a striking proof of the groundlessness of the fears alluded to in a former page, that the mere friction of one pair of wheels upon the rail suffices to draw forward, at express speed, a ponderous train. Engines, however, which are built for "goods" traffic, have commonly "coupling-rods" which connect the driving wheels with the 2 other pairs, which in this case must be of the same diameter: thus all the 6 wheels are actuated or made to revolve by the motive power. Now, although this arrangement does not increase the actual power of the engine, (for this depends on the extent of evapo-

rating surface in the boiler, and on other circumstances), yet its tractive or dragging efficiency is greatly increased by the coupling, since the friction with the rail is multiplied threefold. Every one must have observed that in starting a passenger train the driver not unfrequently drives the wheels round with great rapidity for a moment or two, with the intention (we fancy a mistaken one) of overcoming more speedily the *vis inertiæ* of the carriages. In the goods engine, however, this slipping round of the wheels is nearly impossible, the amount of friction being so great in consequence of its distribution over six points instead of two. Hence the goods engine is capable of drawing after it, even when the rails are slippery, very enormous loads.

We happened to be present, a short time ago, at an occurrence which impressed us greatly with the immense power of these engines, and the extraordinary efficacy of the common rolling friction, formerly so much distrusted. On a dark night, and in a lonely part of the line of the London and North Western Railway, a goods engine, yoked to a train of eighty-eight loaded wagons, had come to a stand in consequence of the breakage of one of these coupling-rods. On hearing the distant whistling, we roused the village blacksmith and his mate, and hastened to the spot, where the driver and fireman were already engaged in removing the couplings, an operation which gave us all full occupation for at least an hour. When this was effected, the engine was of course left with but one pair of wheels as "drivers," the other two pairs being disconnected from the pistons, and merely supporting the boiler, &c., as in passenger engines. Yet with this one pair of driving wheels, the noble machine drew off its 88 wagons with

apparent ease, and without any sign of slipping! We have no data before us for estimating the aggregate weight of such a train; but we believe we are not wrong in assigning an average weight of 3 tons to each wagon or truck *when empty*. Even if the train had been unloaded, therefore, we have here a gross weight of 264 tons drawn by an engine acting on one pair of driving wheels. But if we assign to each wagon the very moderate average load of 2 tons, we have then a total weight of 440 tons maintained in rapid motion by an engine weighing (say) 20 tons, and operating on the surface of the rail at 2 points only. In other words, the engine is drawing 22 times its own weight. This may be instructively compared with the conditions imposed by the Manchester and Liverpool directors, in 1829, on the competitors for their prize.

We may add here that the old method of estimating the power of an engine by its "horse-power," is entirely delusive and inapplicable in the case of locomotive engines.

We must next notice, in connexion with the wheels both of engines and of carriages, one of those simple yet beautiful contrivances which are so characteristic of this mechanical age, and which especially mark the progress of the railway system.

A casual observer might imagine that the wheels of railway vehicles are not only perfectly circular, but also perfectly *cylindrical*. Many, we doubt not, are under the impression that if they cut off from a round ruler a series of discs, (like draughtsmen), and provided each of these discs with a flange or rim of paste-board, they would correctly have represented in miniature, the wheels of railway carriages. But this is not so. The wheels

are *conical*, not cylindrical: they are portions (or "frusta") of cones, not of cylinders. Our toy models will be more correctly represented by slices from common bottle-corks, which have a tapering or conical figure; the flanges being attached to that side of the slice which has the larger diameter. —The reason for this conformation we will now attempt to explain.

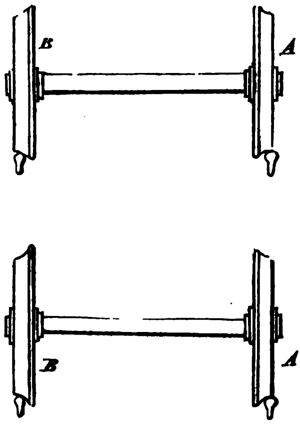
We have already remarked, in a former page, that a considerable play or difference is allowed between the guage of the wheels and that of the rails. The carriages are retained upon the line simply by the flanges or rims, which project on the inner side of the peripheries of the wheels; but it is extremely desirable that these flanges should never actually touch the rails, except when some unusual force tends to remove the carriage from the track. If the flanges, on either or both sides, were perpetually grating against the side of the rail, it can easily be imagined that an immense additional friction would be created; not to speak of the wear and tear of the rail, and of the danger of the wheel crossing or leaving it if the flange encountered even a trifling projection. The problem, then, is, how to keep the carriages in the centre of the track without the actual lateral operation of the flanges. The accompanying figures show how this is effected by the conical structure of the wheels.

The upper diagram represents the wheels in their normal or proper position upon the rails; the flange on neither side being in contact with the rail. In the lower diagram, we have shown the position of the wheels when some lateral force has brought the flange nearly into contact with the left-hand rail.

Now, in consequence of the rounded surface of

the rail, each wheel rests upon it at one point only.* Consequently, while the larger diameter of the left-hand wheel traverses the rail on that side, the smaller diameter of the right-hand wheel will be brought to bear on the other. But a wheel of larger diameter covers more space at each revolution than a wheel of smaller diameter: and if they are fixed firmly on the same axle the larger wheel will describe a portion of a curve or arc round the path of the smaller wheel,—as may be easily proved by rolling on the table a hand-bell, or candlestick, or similar conical object.

Fig. 18.



CONICAL STRUCTURE OF WHEELS.

If, then, the difference of diameter between the outer edge of the wheel A, and the inner periphery of the wheel B, be such that the *circumference* of the latter periphery exceeds the circumference of the former by 2 inches, it follows that in the position figured in the diagram, the wheel B will advance 2 inches further than the wheel A for every revolution they make. The tendency of this will be to move the carriage through a very small arc towards the path of the wheel A;—in other words, to restore the wheels to the position shown in the upper diagram.

* This fact must increase our astonishment at the effect of friction in giving tractive power to engines.

If we have succeeded in making this clear to the reader, he will join us in our admiration of this beautiful arrangement. The wheels are endowed, he will see, with a self-adjusting ever mutually corrective power: no sooner does one side approach the rail, than the other, dropping a little behind, drags it back: if the reaction be too great, this other side, pushing forward, restores the equality!

This operation of the conical wheels is amply sufficient to retain the carriages in their proper position on straight portions of the line: we have already described, in treating of the Permanent Way, the no less beautiful method of preserving that position, during the traversing of curves. The super-elevation of the outer rail, the conical figure of the wheels, and the rounded surface of the rail, thus combine to ensure the safety and ease of the traveller.

It is obvious, that the strength of the axles is a matter of vital importance in the construction of locomotive engines. Until recently, the main or centre-axle was always provided with two cranks, (at right-angles to each other) to which the power of the steam in the cylinders was directly applied. The cranked axle, however, is essentially weak in its form: and it is necessary to make it extremely massive and heavy to enable it to bear the strain of the motive power, together with its due portion of the total weight of the entire machine. To obviate this inconvenience, engines are now built with outside cylinders, acting directly upon a pin fixed on the wheel itself, as in the Rocket. The cylinders, however, in these elegant modern engines, are placed in front, just above the fore pair of wheels. By this mode of construction, the main axle can be made, not only straight, but hollow.

The Locomotive Superintendent of the northern division of the London and North Western Railway,—a gentleman who bears the honoured name of Trevithick,—has brought out an engine of very novel construction, intended for the attainment of very high speed with perfect safety, on narrow-guage lines. Our mechanical readers may remember this engine,—the "Cornwall,"—in the Great Exhibition of 1851. The driving wheels being of great size, the boiler was hung beneath their axle. The centre of gravity is thus extremely low.

Other ingenious and scientific modifications, among which we may specially distinguish those of Mr. Crampton, well merit our attention, if our destined limits permitted us to notice them. Unless some lighter and more compact prime mover be discovered, it is hard to see how any material improvements can be effected in our present locomotive engines.

Having glanced hastily at some of the less obvious, but not (we hope) least interesting features of a Railway Locomotive, we proceed to subject to the same kind of scrutiny, the carriages composing the trains. Their external appearance is now familiar to every reader. With the good taste which generally attends mechanical adroitness, our railway coach-builders commonly prefer the sober colours of claret and dark green, to the more brilliant yellow, red, or blue, which still dazzle the eyes of beholders on the panels and wheels of the town chariot, the park phaëton, or the "knowing" dog-cart. A new first-class carriage, just brought out, clean and bright, for its first journey, is certainly an extremely handsome vehicle; from the lamps at the top to the wheel-tires beneath, every part is well finished, and turned out in a

style which we cannot designate better than by the epithet "workmanlike." The interior has certainly reached the utmost limits of comfort, and even of luxury. We are glad, however, to see that the violent contrast which at one time existed between the comfort of the first-class, and the *dis*comfort of the second and third, has been very much obliterated. The second or third-class traveller needs and deserves protection from the weather, fully as much or more than the well-clad occupant of the coupé: and while it is perfectly right, that the wealthy man should be able to purchase the *luxuries* of travelling, it is but just that the needy man should not be deprived of the *necessaries* of shelter and light. We are glad, therefore, to see the handsome and commodious vehicles which are now built for second-class passengers, and to notice that in some instances, they are furnished with cushions,—in all, with lamps; while the closed third-class carriage affords to the poor man a conveyance infinitely superior, in whatever light we view it, to the stage-coach or the lumbering wagon, which a few years ago would have been his only means of transit.

It is not, however, the comforts or discomforts of the interiors to which we desire to call the reader's attention, but rather to certain contrivances which promote his ease and safety more than cushions or paddings. The first of these, which we shall notice, is known by the name of the "buffers."

Every one who has entered a London omnibus, knows how disagreeable are the consequences of that sudden pull up, and equally sudden move on, which the poor patient horses have learned to connect with the magic terms—"'old 'ard!"—"all right!"—bellowed by the cad, or with the banging

of the door, substituted for the latter phrase by "gents" wisely economical of their lungs. While you are looking for a vacant nook in the crowded vehicle, the signal is given, and instantly you are deposited in the lap of the stout lady behind you; before you have time to apologise, a sudden stoppage jerks you forward into the arms of the gentleman seated at the top, who good-humouredly assists you to your seat in the corner.

Now this unpleasant jerk, or starting, or stopping might be productive, in a railway train, of consequences much more serious than the discomposure of a stout lady, or the embarrassment of a shy gentleman. We may fairly assume, that all our readers are aware that every body in a state of motion, acquires a force, called momentum; and that this momentum is in direct proportion to the velocity, and also to the mass, of the body in motion. This momentum, or impetus, is shared by all the component parts of a compound body in a state of motion; thus the rider shares or partakes of the momentum of the horse, and many of the surprising feats of the circus are in reality much less difficult than they appear, from the operation of this law. When the performer leaps from the back of the horse through a hoop, or over a blanket, held in his course, he has, in fact, merely to spring upwards to the requisite height, the momentum of the horse carries him forward or over. The same law is less agreeably, but more forcibly illustrated and brought home to the senses, when some young beginner in the equestrian art, finds himself projected neck and heels into a ditch by the momentum of his horse, who has prudently stopped to reconnoitre the place, but without previously warning his inexperienced rider of his intention so to do.

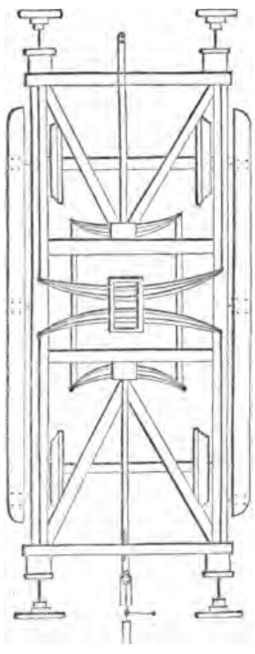
It will easily be conceived, that the momentum of a railway train is enormous. Its amount may be estimated by the sad consequences which ensue when that momentum is suddenly checked, or as suddenly imparted to an object previously at rest. When any casualty suddenly arrests the motion of the engine, or of the fore part of the train, the hinder portions still urged forward by the common impetus, rush over the disabled carriages in front, mount upon them, and become piled one upon the other in an inextricable mass of ruin. Or if, by some unhappy neglect of ordinary precautions, a train at full speed runs into another in a state of rest, while the hindmost carriages of the latter are utterly destroyed, the foremost break loose, and dart forward, impelled by the momentum imparted to them by the collision. Any one may convince himself of this, by laying a few billiard-balls or marbles in a row upon the table, and by then bowling another ball or marble so as to strike the end of the row. This striking ball will be brought to rest, but that at the *other end* of the row will fly off, and proceed in the same direction as the ball you rolled.

Now, although no human contrivance can at all times avert the occurrence of calamities, which may arise from causes beyond our control, yet the dangers arising from the sudden checking of momentum, are greatly diminished by the use of "buffers." At any rate, the ordinary stoppages and startings of a train can now be effected without any jerk or concussion.

We have figured the under part of a railway carriage, as it may be supposed to appear when the body is removed. The round knobs or discs of the buffers are fixed, it will be seen, on sliding

bars which impinge, at their other extremities, against powerful springs, secured to the bed of the carriage. On any check being given to the momentum of the carriage, these springs receive the shock, and by their elasticity destroy or absorb it.

Fig. 14.



BUFFERS AND DRAW-BARS.

The contrivance by which the jerk is avoided in starting, is identical in principle. The hook by which each carriage is attached to its predecessor, or to the engine, is formed upon the end of a bar, which slides through sockets, and is connected with the middle of a stout spring whose ends are fixed. Now, on applying the motive power to the engine, its momentum is first communicated to these springs, and the inertia of the carriage is not suddenly and rudely, but gradually, overcome.

The common luggage wagons are not provided with buffers or spring draw-bars: and we have only to observe the departure or arrival of a goods train to perceive how violent is the concussion which in passenger trains is prevented by these useful contrivances.

The buffers and draw-bars, however, serve

another purpose, besides the one most obvious and patent. They tend greatly to diminish the lateral or rolling motion which is destructive of all comfort to the traveller. The reader has doubtless noticed that the carriages are not simply connected by chains; but are linked one to another by a little apparatus in which the power of the screw is brought into operation. The coupling-links consist of two oblong loops of iron, one end of each of which is formed into a nut for the reception of an iron bar, having a screw cut on the greater part of its length. The thread of this screw is so arranged, that on turning the bar, the two loops approach each other: and a lever, terminated by a heavy ball, is connected with the middle of the bar for the purpose of turning it round. The links of this apparatus being slipped over the hooks on the draw-bars of two adjacent carriages, the screw is turned until the buffers are not only in close contact, but are in some degree compressed by the force applied; and the friction between the faces of the two pairs of buffers will be sufficient to prevent, or at least to check, the tendency of each carriage to roll or oscillate laterally, independent of the other. The whole train thus becomes a continuous line, flexible indeed, but sufficiently rigid to secure a steady and uniform forward motion: the efficacy of the contrivance is sufficiently proved by the ease with which the small type of a newspaper can be read in a railway carriage. Whenever a rolling or lateral motion is perceived, it may generally be checked by turning the screw of the coupling-links.

The "breaks" are contrivances for stopping the train. They consist of blocks of wood, (commonly willow,) forced strongly against the peripheries of the wheels by a system of leverage. The tender is

provided with a powerful set of these breaks; the guard's van has another; and the joint operation of these brings the train to a stand at the desired spot. When the sudden appearance of danger requires a very energetic application of the breaks, the driver assists their action by reversing his engine, that is, by causing the wheels to revolve in the direction opposite to that of his progress. These combined forces, however, occasionally fail to prevent collisions, when foggy weather or other causes have prevented the usual warnings from being given. The porters at a station facilitate the stoppage of the trains in moist weather by throwing a little sand upon the rails.

We will only remark, in conclusion, that the carriages and other vehicles which compose a railway train are necessarily costly. A first-class carriage is said to cost 500*l.*; second and third-class carriages, not less than 200*l.*; vans, horse-boxes, goods wagons, and similar vehicles, from 100*l.* to 150*l.* each. We have mentioned 2,200*l.* as an average price for the locomotive engine. Our readers may have some conception, therefore, of the large amount of capital invested by a railway company in what is called "rolling stock:" and of the heavy pecuniary loss entailed on the company by any destructive accident.

CHAPTER V.

THE ATMOSPHERIC AND ROPE RAILWAYS.

We have already hinted, that other modes of traction, besides that by steam locomotives, have been partially adopted. We shall devote this chapter to a brief examination of these modes of traction; for though they must undoubtedly be considered as failures, when compared with the system now so prevalent and so triumphantly successful, yet they belong to the history of railways, and must not be omitted entirely from a work which aims at giving a popular sketch of their rise, progress, and present state.

We commence with the Atmospheric Railway: an invention marked by very great originality in its first conception, and by remarkable ingenuity in the details of its construction; but which has, nevertheless, disappointed the hopes of its projectors when brought into operation on a large scale.

The idea of employing the atmosphere for the propulsion of carriages seems to have first occurred to a Mr. John Vallance, of Brighton, who proposed to form tubes large enough for the passage of the whole train: and thus to blow the carriages from end to end like pellets through a school-boy's pea-shooter! It may fairly be doubted, we think, if this novel mode of travelling would have found much acceptance with the public, who *might* pos-

sibly have objected to being thus blown through the barrel of a huge air-gun.

A Mr. Pinkus, however, came forward to calm the fears of travellers by undertaking to convey them outside, instead of inside, the tube: and it is to this gentleman that Messrs. Clegg and Samuda (who are usually considered the "inventors" of the system) are certainly indebted for all the essential features of their plan.

The Atmospheric Railway, as patented by them, consisted of a tube or pipe of cast-iron from 15 to 18 inches in diameter, firmly secured between the rails, and extending continuously from end to end of the line; or, at least, only broken or divided at intervals of about 3 miles. The reader will understand our description better, if we confine ourselves to an explanation of the principle, and of its action, as shown in one of these three-mile sections.

Let us first suppose, then, that within the cast-iron tube is placed a piston or disc which fits it accurately, though capable of sliding from end to end of the tube. Let us suppose one end of the tube to be closed or stopped: the other to be open, or rather to be occupied, for the present, by the piston just described. Now, the reader is aware that the atmosphere presses all bodies which are exposed to it with a force or pressure of about 15 lbs. to each square inch of surface; and that this pressure is exerted equally in all directions. In other words, if he stretches out his open hand, the air presses on it, not only above, but also below, at the sides, and around, with a pressure of about 15 lbs. on each square inch. He is not sensible of bearing any such weight, because the pressure below his hand exactly counterbalances the pressure

above: but let him lay his hand upon the open top of a jar, resting upon the plate of an air-pump; let the pressure of the air be withdrawn from below by working the pump, and we can assure him he will soon be sensible how vast a power resides in that transparent and invisible medium in which we live.

The piston, then, in the position we have described, is acted on by two equal forces, on its opposite sides: viz. by a pressure of 15 lbs. per square inch caused by the external air; and by a pressure of 15 lbs. per square inch caused by the included air in the section of the tube. Now, let us remove this latter pressure by pumping out the air: and for the sake of clearness, let us suppose a perfect vacuum created in the tube. We have now, on the one side of the piston, a pressure of 15 lbs. to each square inch; on the other side, we have no pressure at all. It is of course evident, therefore, that the piston will be urged forward with a force represented in lbs. by the number of square inches of its surface, multiplied by 15. With a piston 18 inches in diameter, this pressure, or force, would amount to nearly 4,000 lbs.,—a pressure more than sufficient to draw a loaded train with very great velocity. As, however, it is practically impossible, and indeed undesirable, to obtain a *perfect* vacuum in the tube, we may assume that half the total pressure of the atmosphere is employed by the partial rarefaction of the included air; and we have then (in round numbers) a tractive power of 2,000 lbs. at our disposal. This tractive power, we learn from a very competent authority, is capable of drawing a train weighing about 55 tons on a level line at a speed of 30 miles an hour.

We have yet to show, however, the means by which the piston, impelled by this enormous force,

was enabled to communicate its own motion to the carriages outside the tube. Having pointed out the pneumatic principle, we come to the mechanical details.

The tube was provided, along its entire length, with a slit or opening about 2 inches wide. This slit or opening was closed by a valve of leather, strengthened by iron plates, and rendered air-tight by a composition of bees-wax and tallow, sealing hermetically its junction with the tube. An iron plate called the "coulter" was attached to the piston, and, passing upwards through the opened valve, was connected with one of the carriages of the train. The action was as follows: —On a signal being given, the air-pumps, worked by powerful steam-engines, were put in operation. A partial vacuum having been thus created in the tube, (closed hermetically by its valve,) the piston was impelled forward, as already explained. Small wheels, attached to the bar which carried the piston, forced open the valve sufficiently to permit the passage of the coulter; and behind it rolled a wheel which again closed the valve; while a small stove, passing over the slit, melted the composition, and effectually sealed the opening.

The reader will agree with us in regretting that an invention so beautiful in theory, and so ingenious in detail, was not found to answer in its practical application. We have spoken of it throughout in the past tense; for we believe it has been abandoned, as a mode of traction, in every instance where it has been fairly tested.

If the difficulties which led to its abandonment could have been surmounted, the Atmospheric Railway held out many advantages to tempt the engineer and the shareholder. The rails, not

having to support the great weight of the locomotive engine, and being exposed to none of the wear and tear caused by locomotive propulsion, might have been made much lighter, and been laid down at much less cost. At the same time, since much steeper inclines could have been ascended, the expense of forming the line itself would have been greatly diminished. Lastly, it was said that the cost of working the atmospheric line would be much less than that of locomotive traffic, since the stationary engines would burn cheaper fuel, and require less repair, and fewer attendants; while in certain situations the economical power of water might be called in to supersede that of steam in working the air-pumps.

We believe the difficulty of maintaining even a partial working vacuum was the cause of the failure of the Atmospheric Railway. The word "impossible," however, is expunged from the vocabulary of the modern engineer: and the pneumatic principle may yet, at a future day, be successfully applied to the propulsion of trains.

The writer made a journey on the South Devon line soon after the substitution of locomotive for atmospheric power. It was not a little curious to find one's self ascending laboriously a *steep hill* on a railway: and it was perhaps somewhat trying to the nerves of timid persons when the train, by the action of gravity alone, descended with almost lightning speed the opposite slope. We know not if these gradients have been altered. They were certainly quite unsuited to locomotive traction, though they added not a little to the interest with which we traversed that beautiful and picturesque line of railway.

The method of traction formerly adopted on the London and Blackwall Railway, merits some slight notice; for though it has now given place to locomotive power, it cannot be said to have failed in its application to the short line on which it was first used.

We may describe the tractive power, succinctly, as that of stationary steam-engines, applied to wind a rope upon drums or barrels at each extremity of the line. Simple as this elementary idea may seem, it yet involved many ingenious adaptations of mechanical resources in its practical working.

The line is somewhat more than three miles in length: and in this short distance there are no less than seven stations. Now, even if the traffic were conveyed by locomotives, there would be a great inconvenience in making seven stoppages in a total length of three miles; but it is evident, that where the motion of the train depends upon the action of a steam engine at the terminus, the stoppages would become not merely inconvenient, but almost impossible. Even supposing that by the Electric Telegraph notice were conveyed to the engineer of the exact moment of arrival at each station, still the very grave objection would remain, that a serious wear and tear would be the result of such frequent changes from motion to rest, and *vice versâ*, of a rope 6 miles in length, and weighing 40 tons.

This inconvenience, then, or difficulty, was obviated by a clever arrangement.

Let us suppose that a train of eight carriages was about to leave the London terminus. The passengers were seated in them according to their destinations; those who were proceeding to the nearest station being in the hindmost carriage, and

each of the other carriages being similarly appropriated to the passengers for each station on the line; the Blackwall passengers being in the leading carriage. Each carriage was attached to the rope independently of the others, and in such a manner that it could be disengaged at any moment, and brought to rest by breaks.

When all was ready, a signal was given by the Electric Telegraph to the attendant at Blackwall; who immediately put the steam-engines in motion. The drum upon which the rope was wound was of cast-iron, and about 23 feet in diameter. It was driven with a velocity equal to an average speed of 26 miles an hour; and at this speed all the carriages were drawn along together until their arrival at the first station. Here the last carriage was disconnected and brought to a stand; the others proceeding with undiminished speed. At the next station, another carriage was left; and so on, until the leading carriage arrived at Blackwall.

But, though it arrived alone, other carriages had arrived before it. From each station on the line, a carriage had been despatched to Blackwall. This will be easily understood, if we imagine ourselves making the return journey. The carriages which we left at each station are connected each at its proper point, with the rope, which is now at rest; half of it being wound upon the drum at Blackwall. At the latter terminus, eight carriages, as before, are independently attached to it. Now, it is evident, that on working the London engines, the carriages from each station will successively be drawn back to the terminus; and, as before, one carriage only will make the whole journey, its companions having been left, one by one, at the different stations.

For simplicity's sake, we have supposed one carriage travelling to and fro between each terminus and its respective stations: practically, however, two or three stations which are very near to each terminus, communicated only with the more distant one. It is evident, also, that the number of carriages could be multiplied according to the requirements of the traffic.

The rope was supported throughout its entire length on wheels or sheaves, 3 feet in diameter, placed at short intervals along the line. The noise made by these appeared to us much greater and more unpleasant to the ear than that occasioned by an ordinary train.

CHAPTER VI.

THE ELECTRIC TELEGRAPH.

INTIMATELY connected with the railway system, (in England at least,) the Electric Telegraph claims some notice in a work such as this.

Of all the marvels of modern science, this is perhaps the most astonishing. The railway itself, with its rapid trains, is a wonderful illustration of the triumph of skill and energy, over the natural laws of time and space; our minds, now familiarised with the externals of the system, are seldom, perhaps, exercised in reflecting upon the internal principles which govern it, but yet the slightest consideration must convince any thoughtful person that in the passage of an ordinary train, he witnesses a sight in every way remarkable. That that mass of weighty matter should be impelled more swiftly than the race-horse, by a power which is absolutely *invisible*,—which has no "form," though it exerts sò mighty a "preŝsure,"—in short, that that train of passengers or goods, should be drawn along literally with the speed of the wind, by an agency as subtle as the air itself, is one of those facts upon which the mind never can dwell without astonishment.*

* It must be remembered, that pure steam is wholly invisible to the eye. The white vapour which issues from the safety valve of a boiler is steam partially condensed, and charged with watery particles. Smeaton computed that the speed of a "high wind" was about 30 or 40 miles an hour.

It is really somewhat less marvellous, that an agency yet more subtle and impalpable than steam should be employed to convey "winged words," with a velocity which the mind is incapable of estimating, from one region of the earth—or air—to another. If the expansion of a few drops of water suffices to impel enormous weights, living and dead, in the teeth of an opposing gale, at a speed exceeding that of the gale itself, we accept with greater readiness the proposition to convey words which, however important they may be, are altogether weightless, by the operation of electricity.

The success, however, with which that proposition has been realized, the results which have attended that realization, the machinery by which those results are attained; the simplicity of the machinery, which is easily controlled by boys of tender age,—all invest this creation of modern science with an air of romance, which gives it an indescribable interest for all who witness its operation.

The extreme celerity with which intelligence can now be communicated between points situated many hundreds or thousands of miles apart,—for distance is literally annihilated by electricity,—is such as to excite the utmost astonishment. The poet, who gave wings to the impersonation of Rumour,* never conceived a flight so rapid as that of the unseen messenger, which now conveys tidings of weal or woe, of loss or gain, of hope or fear, along the wires of the Electric Telegraph. At the moment we write, operations of a warlike tendency, in which England is directly interested, are taking place on the frontiers of European

* "Fama volat." Virgil, passim.

Turkey; and intelligence from the scene of action up to the latest date is eagerly sought In consequence of the extensive adoption throughout Europe of the Electric Telegraph, this intelligence is now communicated to England, printed in our newspapers, and meets our eye on the breakfast-table, within a very few hours after the occurrence of the events. The actual time consumed in the passage of the electric fluid is inappreciably small—when we inform the reader, that its speed is not less than 288,000 miles *per second*, we feel we have done nothing to assist him to a conception of such velocity.

Instead of placing before him figures and calculations, which tend rather to bewilder than to inform the understanding, we shall endeavour to explain the general laws on which the Electric Telegraph depends, and the apparatus by which its almost miraculous performances are effected. We have remarked, that both are simple; and as we are unable to refer to any really plain and popular description of the scientific features of the Electric Telegraph, we shall now try to supply one.

We commence by stating the general law, that electricity is conveyed by conduction through metallic substances with greater facility than through other solids. Thus, the electricity with which the atmosphere is charged during a thunderstorm, is conveyed to the earth by "lightning conductors," which are simply vertical rods of metal, armed at the top with points, and descending several feet into the ground. The electric fluid does not strike the chimneys or the neighbouring trees, because the metallic conductor presents greater attracting power, but the conductor itself must be carefully "insulated," or attached to the wall by some non-

conducting material, otherwise the current may diverge from its course, and the mischief may ensue which the conductor is intended to avert.

Now, let us suppose such a conductor stretched horizontally between two points, separated by a distance of ten or more miles. It is supported by upright posts, and the points of its attachment to these posts are provided with a little apparatus to insure its insulation. A stream of electricity may now be transmitted by conduction from one point to the other, with the inconceivable velocity to which we have already alluded.

This stream is generated, not by "electrical machines," which act by the friction of non-conducting substances, (glass, or resin, or silk,) but by the Voltaic or Galvanic Battery. This apparatus consists of many pairs of metal plates,—generally copper and zinc,—arranged alternately in a trough containing water, mixed with about $\frac{1}{12}$th of its weight of sulphuric acid. If, now, the zinc plate at one end be connected with the copper plate at the other by a wire, an active current of electricity will immediately be created. The reader may try the effect of this, by making a "pile" for himself. Let a number of copper coins be arranged in alternate layers, with zinc discs of the same size, and with circular pieces of wet pasteboard or cloth, thus,—(1) copper, (2) zinc, (3) cloth,—to any convenient extent. Let these discs be kept in their places by glass rods, passed through holes in two wooden boards. Each end, or "pole," terminates with a copper and a zinc plate respectively; and to these terminating plates, wires are soldered or otherwise attached. So long as the pasteboard or cloth continues moist, a current of electricity will pass from one pole to the other, when the ends of

the wires are brought into communication. The operator will be sensible of this fact, if he makes himself a part of the circuit by grasping one end of the wire in each hand. He will experience a peculiar and disagreeable sensation in the joints of the elbows and wrists; and this sensation, or "shock," will be shared by any number of persons who may join hands, and form a part of the conducting medium.

Suppose, then, a battery, or pile, in action at one of the extremities of the proposed line of communication, and that the wire from one pole is carried to the other extremity, and thence returned to the opposite pole of the battery.* The distant town is now part of the circuit of the electric fluid; and every point in the wire is subject to its influence, just as the circle of persons joining hands felt equally the shock in the experiment above described.

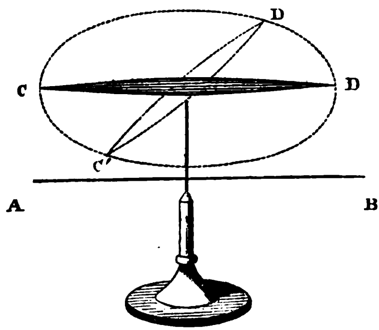
We have established, then, a communication between the two points; but now, how is that communication to be made available for the transmission of intelligence? Already, we may give a "rap on the knuckles" to some unlucky meddler with the wire, but how are we to acquaint him with the causes of our displeasure, or with the wants, wishes, hopes, fears, and anxieties of the little world ten miles from him?

Now, here we must state another general law. If a magnetic needle, poised on a pivot, be brought near to a wire through which an electric current is passing, it will tend to place itself at right angles to the wire; the direction of its movements obeying

* This return wire is not now used. The current returns, it is found, through the earth, or rather through the moisture in the earth.

certain laws. Thus, in the adjoining figure, if A B represent the wire, and C D a magnetic needle, poised on a pivot so as to revolve freely; on

Fig. 15.



PRINCIPLE OF ELECTRIC TELEGRAPH.

transmitting a current of electricity along the wire, the needle will tend to leave its parallel position, and take up another position, at right angles to the wire, as shown by the dotted lines.

If now, such a needle be placed at each point of communication, on completing the circuit, the needles will be *similarly* deflected at both ends simultaneously; and if we have preconcerted some simple code of signals, we can transmit any short and easy messages, by regulating the number or extent of the deflections of the two needles.

Having thus pointed out,—we hope intelligibly, —the manner in which messages may be transmitted, let us describe more particularly the method actually employed. It will be found that mag-

netism is still the agent in use, though under a modified form.

Among the very singular phenomena of magnetism, there is none more singular than its close connexion with the voltaic current. When a piece of soft iron is exposed to the action of the current, it instantly becomes a magnet! while, on withdrawing the electric influence, it again loses its magnetic powers. Professor Wheatstone has availed himself of this surprising fact in the construction of the present telegraph. A number of short cylinders of soft iron, are converted into electro-magnets at pleasure by the transmission of the voltaic current. These temporary magnets attract or repel "keepers," which are so arranged as to give a circular motion to index-hands or pointers. Then, on placing these indices in a certain position at one end of the line, all the indices in connexion with the wire, assume a similar position; and by a preconcerted code of signals, any message may be transmitted, either letter by letter, or by symbols which denote the words in common use, as in short-hand.

The external appearance of the instruments is probably familiar to all our readers. A case, made of mahogany or rosewood, about the size and shape of an ordinary time-piece, stands in some convenient part of the office, or has an office to itself. On the face of this little ornamental cabinet, appear two needles or pointers, together with several letters, names, and short words. Above it, in a little belfry of its own, is an alarum or clock-bell; and beneath the face are two stout handles, commonly of brass. On moving these handles through part of a revolution to the right or left, the voltaic current is made to magnetise

the cylinders of soft iron (about 2 inches long, by ½ an inch in diameter) contained in the case. The moment these cylinders are subjected to the electric influence, they attract certain "keepers" or pieces of steel or iron; and these keepers, by an ingenious mechanical arrangement, give a rotatory motion to the needles, which motion is copied or exactly imitated by every needle connected with the wire along the whole line of communication. When the electric current is interrupted, the cylinders cease to be magnets, and consequently no longer attract the keepers, which are then pushed back by a spring.

It is most interesting to watch the electric telegraph in action. We are almost tempted to say, it is worth while to lose some article of luggage on a journey, for the pleasure of seeing electrical inquiries made and answered. The clerk grasps the two handles, and proceeds to work them somewhat violently, with a peculiar jerk of the wrists. He is ringing the bell at the station, two hundred miles off, at which your luckless portmanteau is supposed to be left. He tells you he can't catch the other clerk's attention; the latter has just stepped out, he supposes,—perhaps to his dinner. How the whole scene is brought vividly to your imagination by this strange annihilation of space! You picture to yourself the station, the platform, the very spot on which you last beheld your hapless baggage, the very porter who faithfully promised to place it in the van!—All this time the clerk is twisting and agitating the handles;—and now, ah! here he comes at last! The other clerk hears the bell; and in your mind's eye you see him running towards his office, his mouth still full of bread and cheese! The

handles are moved more slowly:—two twists, and a stop: three twists,—the needles swing backwards and forwards.—"A portmanteau,—Up night mail, —direction, A. Careless, Esq. London."—He understands us; he is making inquiries. Give him time. Now our bell rings,—we answer, we are all attention. "The portmanteau is here; it will be sent by the next train." You are civilly assured that if you will come again at 8.45, you will receive your property.

We have sketched a trifling incident; but let the reader reflect what a very great blessing this invention may prove in cases of sickness or other emergency. How many lives have been saved already, by the power thus given of summoning quickly the best medical aid! How many deaths have been deprived of half their bitterness, by the presence of some whom the electric wire has called to the bed-side! and if—which may God avert!—the peace of our country should ever be broken by foreign foe or domestic outbreak, how important that slender thread of iron which gives the word of command at the distant barrack, and puts in instant motion the force required!

We should far transgress our limits, if we were to indulge in the reflections aroused by the subject before us. We cannot help, however, calling the reader's attention to one view of the subject, in which he will doubtless join his feelings of congratulation with our own. We mean, the great saving of human and other animal life which will certainly be effected by the scientific discoveries of these days. Experience has taught us, that as we increase the efficiency of warlike implements, we diminish the amount of bloodshed. The victims of Salamis far outnumbered those of Trafalgar;

the slain at Waterloo bore no proportion to those at Marathon. And in any future war, we may trust that the immense facilities for referring diplomatic difficulties to the home government, the power of concentrating bodies of troops, or squadrons of ships propelled by steam power, on any desired point, the perfect understanding which may be maintained between the generals or commanders of distant armies and fleets, will greatly shorten the contest, and abridge the horrors ever attendant upon warfare. At any rate, no such unfortunate event as that which took place at Toulouse in 1814—viz. the occurrence of a general engagement after peace had been proclaimed in the capital of the country—can ever again blot the page of history.

We shall be pardoned, we trust, if we add an expression of our sincere joy, that intelligence can now be transmitted without taxing the strength and endurance of the poor horse. The praise bestowed on the riders of expresses who brought extraordinary news to the capital, should surely have been given to the noble animals which carried them. There were not wanting many persons whose minds dwelt with pain on the thought of the gallant horse, urged far beyond his strength, merely that a particular editor might have the honour and glory of publishing certain items of news before his "contemporaries." All this is now a thing of the past. The Electric Telegraph effects its mighty achievements without pain or suffering to any living creature, and causes no inconvenience to its attendants, more serious than that of being summoned from their bed or meal to hearken to its whispered words.

CHAPTER VII.

THE STATIONS AND SIGNALS.

We have intentionally postponed our notice of the stations and signals of a railway, until after our remarks upon the Electric Telegraph, because the reader, who has been kind enough to accompany us thus far, will now have much less difficulty in understanding the rules and regulations by which the traffic between the various stations and the terminus is governed and conducted.

It is not our present purpose to say much of the architectural features of railway stations. We shall not offer any criticism upon the very different styles adopted by our engineers; and shall leave our readers at liberty to form their own opinion as to the suitableness of the Grecian portico at Euston Square, the Italian campanile at London Bridge, the Elizabethan mansion at Chester, the collegiate group of buildings at Stoke-on-Trent, or the castellated pile at Bristol. We shall not discuss (with our coffee) the arabesques of the refreshment rooms at Swindon, nor carp (like the accomplished but dogmatic author of the "Stones of Venice") at the stuccoed caryatides of Crewe. One feature we notice with pleasure and with thankfulness; viz. the appearance of a church spire among the buildings which cluster round the midway stations of more than one of our great railway companies. May we not be permitted to regard this recognition of religion amid commercial enterprise as a feature peculiarly English? And is it unreasonable to hope, that while the highest of all interests is thus

cared for, a blessing will be bestowed on the commerce of a country which, amidst many shortcomings and errors, thus publicly proclaims its creed, that "The earth is the Lord's, and all that therein is: the compass of the world, and they that dwell therein!"

Our present business is with the machinery—if we may so term it—of the stations, rather than with their external features: and we may class this machinery or apparatus under two heads, viz. first, the contrivances for the moving, turning, loading, and unloading of carriages and waggons, detached from each other, or in a state of rest; and, second, the important mechanism by which the drivers of trains, when leaving or approaching the station, are warned of danger, or apprised that all is safe.

Under the first of these heads, we must notice the "turn-tables," and other analogous contrivances. It is evident that a railway carriage or engine cannot be turned round in the same manner as vehicles used on common roads. The rails confine the former to one straight line, or rather to a line which only admits of curves of a very large radius. Some mechanism is therefore necessary for reversing the engines and carriages at pleasure. The simple contrivance called a turn-table effects this at once. It is merely a platform of metal or timber, exactly fitting and closing a circular pit dug in the ground. This pit contains the wheels which support the platform, and which resemble those used for wagons; they traverse a circular ring or rail of iron. The main line of rails crosses this platform; and at right angles to it,—both being divided or notched at the angles formed by their intersection,—another line is laid, commu-

nicating with a turn-table on the adjacent line, or with a branch railway, or with the shed in which spare carriages are kept. Stops or catches are so placed as to confine the turn-table to the exact point in its revolution at which the fixed and rotatory lines coincide. Now, if a carriage be drawn on the turn-table, we have merely to cause the whole to perform part of a revolution until the stops fall into their proper places, when the carriage is pushed forward into its desired position, or is transferred to another table, to be turned round as before.

This is so plain and familiar, that the reader will perhaps think we might have spared ourselves the trouble of describing it. We have noticed, however, at some of the stations of the Great Western Railway, a substitute for the turn-table, so ingenious and scientific, that we are sure a slight description of it will not be unacceptable. We sketch it from memory only, and we have not had a very recent opportunity of examining it, or of ascertaining if it is still in use; we have a perfect recollection, however, of the principle, and we believe we shall not err greatly as to the details.

In this contrivance, the carriage is lifted by hydrostatic power, and is conveyed on a traversing platform to any line of rails parallel with that from which it was removed. Let us suppose that in a station there are six or more lines of railway laid down within the building. A carriage, standing on the "Down" or left-hand line, is to be transferred to the "Up" or right-hand side. Now, a cross line of rails is laid in a trench or pit dug from one side of the station to the other. In this trench, a wagon or platform can be made to traverse by means of chains passing over pulleys,

and worked by hand in a manner which may be easily conceived.

This platform, then, can be drawn from one side to the other of the station; and if we can place a carriage upon it, we can effect the desired object of moving it laterally. This was done, in the instance we mention, by hydraulic power. We could not imagine why the porters were pumping water, until we noticed the gradual rising of the ponderous first-class carriage. We need not here explain the hydraulic press: it must suffice to say, that a few quarts of water, rapidly pumped from a cistern, raised the carriage a few inches; and then, the platform being drawn across, it was gently lowered upon the other line. The whole process was effected by a couple of porters, in as many minutes: and though the apparatus may be inferior in simplicity to the common turn-table, it appeared to us that it might economise labour by requiring fewer hands. We do not venture, writing from memory only, to describe the exact manner in which the several lines of intermediate rails were passed, but the principle is worthy of observation, as a proof of ingenuity and science applied to an operation of daily and hourly occurrence.

The sleek, well-fed horses, employed at the greater stations to move carriages to and fro, must, of course, have been noticed by our readers, who have admired, perhaps, the instinct with which the animal proportions his effort to the weight which he is required to move. First securing a good footing, he leans gradually against his collar, and by a steady pull, without jerking, he draws back several loaded carriages.

The process, however, of making up a train of carriages by the use of the turn-tables, of manual

and of horse power, is too familiar to need description; and it is not the province of this little book to enter into details of the internal economy of railway stations, by enlarging upon the number of men and horses, employed at each terminus or junction of a great line of railway, to perform this service. But in glancing at the mechanical arrangements of a station, we cannot but be struck by the great care taken for the safety of the public. Of course, we notice this without surprise; and we should doubtless have a right to be very much astonished and aggrieved if any negligence of the public safety were manifested: but this same "public" is apt to be captious and unreasonable in these matters, and on the occurrence of an unfortunate accident, the outcry against the direction of the company has often, we think, been undeserved. Among the ordinary precautions taken for securing the safety of a train, is that of employing two or more men to strike with a hammer the tire of each carriage-wheel before its departure from the platform. The practised ear of the workman can immediately detect a flaw in the iron, by its resonance under the blow: and if this should be discovered, the faulty carriage is forthwith removed. Every part of the engine, also, is thoroughly examined before it leaves its "stable," or shed, and the slightest defect is registered and made good. When it is remembered that a locomotive engine is composed of an aggregate of no fewer than 5,400 pieces of metal, many of which are fitted to each other, and to their places, with an accuracy unsurpassed in any department of art, it will be seen that no ordinary degree of care and attention must be necessary to enable this complicated machine to "run its course" with safety and precision. At the great midway stations of the

arterial lines, at Crewe and Wolverton, at Swindon and at Doncaster, workshops and machinery on the most extensive scale are erected for the manufacture, but especially for the repair, of the "rolling stock" of the respective companies. It is said that the average annual cost of an engine, in repairs, amounts to 500*l.*!

The engines and carriages, then, minutely examined and tested in every part, are marshalled into trains according to the amount and character of the traffic. The couplings we have already described; and we have only to add that most of the carriages are furnished with lamps, to give light while passing through the midnight darkness of the tunnels.

The busy scene at starting we must leave to the memory or imagination of our readers. We concern ourselves only with mechanical details: but we cannot help casting a backward glance to those bygone days, when journeys were commenced under the very different circumstances which characterised road-travelling. Those who are old enough—and we need not go back very far for this—to remember the days of stage-coach travelling, can hardly credit the fact, that the long vista of carriages which they see drawn up to the platform, and rapidly filled with passengers and luggage, are the substitute for one mail-coach and half-a-dozen "stages," which were found sufficient, twenty years ago, for the conveyance of the traffic. Who can recognise the faintest resemblance to the old "Glasgow Mail," in the train with its "Flying Post-office" and tenders, its array of guards, its host of passengers? In truth, the immense increase of passengers, and development of traffic, caused by the spread of the railway system, is one of the most remarkable features in its history.

And now, the last passenger having been hurried to his place, the bell rings, and the engine, with a few deep-drawn sighs, commences its journey. But the safety of that journey is very materially enhanced by mechanism at the different stations. Of course we allude to the signals.

It must be evident that the Electric Telegraph is a most important aid to the safe working of a line of railway. On some lines,—we believe on the Great Western, certainly on the Eastern Counties',—*every* station is provided with an instrument, by which it can communicate with the other stations above and below it. The departure of a train can, therefore, be notified with the greatest ease to the station-master at the next place of stoppage; and he, on his part, can report himself as ready or otherwise for its reception. On the Blackwall Railway, we have shown that the Electric Telegraph is absolutely essential to the working of the line; and we cannot but think that it should form a part of the apparatus provided at all stations, especially as its management is within the powers of any boy of ordinary intelligence.

Independently, however, of the Electric Telegraph, a system of signals is provided, well adapted for ensuring or promoting safety. We describe those which we have noticed on the London and North Western Railway, though our remarks are for the most part applicable to all the great lines in this country.

The whole system rests on a simple and well defined arrangement of colours, displayed during the day by flags or wooden surfaces; during the night, by lamps. RED invariably implies Danger, or necessity for immediate stoppage; GREEN gives permission to proceed, but with caution; WHITE, or its equivalent, a blank, denotes that all is

right, and the line clear. The mechanism by which these colours are displayed is simple enough. A tall post, or balk of timber, is fixed vertically in the ground: near its summit is a little landing-place, resembling the "top" of a ship's mast, and reached, like the latter, by a slender ladder: on this "top," the porter stands to trim the lamps. Two wooden arms, a few feet in length, play freely upon a pin passed through their ends, and through the top of the post. When allowed to hang vertically, they are concealed within a mortice or long slit in the post; but by the action of a lever and connecting rods, they may, together or separately, be raised to an angle of 45° with the post, or further elevated to a right angle. This last position, the right angle, is equivalent to the Red signal, or "Stop:" the intermediate position corresponds with the Green, or "Caution:" while the dropping of the arm, or the showing no signal at all, implies "All right; go on." The lever, or handle, is so arranged as to move within a segment of a circle, on which are painted the three colours;—(we always wonder, by the way, why the three national colours of old England, Red, White, and *Blue*, were not selected;)—and thus the most inexperienced or illiterate porter can at once place the arms in their right position, by fixing the lever with a pin opposite its proper colour. The same lever governs the motion of slides, like those of a magic-lantern, which close the front of the lamps placed on the highest point, or "truck" of the post. Thus, when the arm is within the post, a white or plain glass is between the flame of the lamp and the eye; on raising the arm to half a right angle, a green glass is interposed; on completing the elevation of the arm, a red glass warns the driver to cut off his steam, reverse his engine, and apply the breaks.

These "Semaphores," as they are called, are visible in clear weather, by day or night, at a considerable distance; we can ourselves distinguish the red, green, and white lights, with perfect ease, of a semaphore situated three miles from our post of observation. But in foggy weather, some additional safeguard is necessary. This is afforded by auxiliary signals placed from 200 to 500 yards in advance of the semaphore, and worked by a wire cord drawn over pulleys, and connected with a lever. The signals, auxiliary to the semaphore mentioned above, consist of a disc of thin iron, two or three feet in diameter, coloured red on one side, green on the other, and provided with a lamp similarly furnished with glasses. This disc and lamp are fixed on a vertical axis, which is attached to an upright post, and revolves easily on a pivot. Now, when the edge of this disc is presented to the eye of the driver approaching the station, it is (from its thinness) a blank, or "all right." When, on the contrary, the broad face is exposed, it is a plain warning (by day) that at the semaphore the red signal is shown; while, by night, the coloured lights are still more significant.

To this account of the stationary signals, we may add that certain movements of coloured flags, hand lanterns, or even of the arms only, are well and generally understood by the drivers of trains. Thus, a person standing by the rails, with his face towards an approaching train, and raising his arms above his head several times, may always arrest the driver's attention, and cause the stoppage of the train. This hint may be worthy of the recollection of our readers, if unhappily they should ever witness a railway accident attended with risk of collision from a following or coming train. On

any accidental stoppage, the first care should be to send some one down the line at least 600 yards, with a red flag by day, or lamp by night, to stop all succeeding trains; and if both lines of railway are blocked, a similar precaution should of course be taken by sending a messenger in advance.

The stoppage of an approaching train, however, under circumstances of danger, is most readily effected by the ingenious contrivance called the "Fog signal," with which all drivers, guards, breaksmen, and labourers on the line are provided. The fog signal is a little packet of detonating composition, provided with two ears or bands of soft lead. It is placed on the rail, and secured to it by bending the leaden ties round the iron. The moment the engine-wheel passes over it, it explodes with the report of a small piece of artillery. On receiving this broad hint, the driver at once stops his train, or proceeds with the utmost deliberation until he discovers the source of danger.

By means of these signals, fixed, moveable, and occasional, the traffic on the line is rendered safe, or is at least made so secure that (without gross carelessness) accident can hardly be the result of any causes within human control. A slip of earth upon the line, a hidden flaw in the material of an axle, may still be followed by grievous injury to life and limb; but these contingencies are not peculiar to railroads. The old stage-coach undoubtedly combined within itself many more elements of danger than the modern railway train. When fully loaded, and carrying its immense burden on its roof, the centre of gravity was so high, that a very slight inclination on one side was sufficient to destroy its equilibrium, while it was a special object with its conductors to load it

in such a manner as to occasion a rolling or swinging from side to side, in order that the weight might practically be supported on two wheels only as the coach rolled forward. To this essentially unsafe machine were harnessed four horses, in the highest condition as to mettle and spirit; and as it was an object of primary importance to beat the "opposition," a gallop was often maintained throughout a whole stage, whatever the character of the road.

We maintain that the train, even the "express," is a much safer mode of conveyance than the vehicle we have described. We believe that a careful inquiry into the statistics of travelling by road and by rail, would show an immense advantage, on the side of the latter over the former, as regards security to life and limb; and that of the millions now annually conveyed at rapid speed by railway, an imperceptibly small proportion meet with accident or even detention. When the vast increase in the number of travellers is considered,—when it is remembered that hundreds of passengers now move from place to place by trains at all hours of the day and night, instead of the few scores of persons who unwillingly encountered the tedium of a stage-coach journey,—it must be conceded that even an equal per centage of fatal accidents would give no fair ground of argument against the safety of railways. We believe, however, that the truth is as we have stated it above—namely, that the railway train immeasurably surpasses the stage-coach in safety, as in comfort and speed; and that in the modern mode of travelling, not only an increase of celerity, ease, and despatch, but also a vast accession of security against accident has been gained by the passenger.

CHAPTER VIII.

CONCLUSION.

In the foregoing pages, we have taken a rapid view of the mechanical features of railways and of railway trains. It may not be uninteresting, ere we close the present treatise, to glance at the railway system in its commercial and social aspect.

We have before remarked, that in England, the initiative, at least of most works of great public benefit, is generally left to private enterprise. The commercial spirit, strong in all the branches of the Anglo-Saxon family, is allowed to be the chief agent in providing the comforts and conveniences of life for the community at large; and although, as a matter of theory, we might wish to trace these conveniences and luxuries to the wisdom of a paternal government, or to the disinterested philanthropy of our rulers, it cannot be denied that in practice they are the fruit of mere mercantile speculation.

All the railways of Great Britain, (and we believe of America) have been constructed by joint-stock companies, whose primary object was not the promotion of public convenience in travelling, but the realization of a profitable return on the investment of capital. Perhaps the direct utility of the railway was the principal end in view in the construction of the Stockton and Darlington, and Liverpool and Manchester lines; but unquestionably the immense profits of these undertakings

were the bait which attracted the projectors of subsequent works of the same kind. Commercial men saw a new opening for the investment of capital, and public convenience was a consideration quite secondary to the paramount interests of profit and loss.

This mercantile spirit, however characteristic of the British race, and however healthy in its ordinary effects, is liable to periodical attacks of derangement or insanity. The year 1845 saw a renewal of the rash and dangerous speculation which had led to the disastrous results of the "South Sea Bubble" a century before. Men of all ranks and degrees shared the mania for railway speculation. The lawyer, the scholar, the tradesman, the squire, became suddenly interested in the fluctuations of the share-market, and the prices of stock. It was said that even the fair sex caught the general infection. The history of commerce contains no page more full of strange romance than that which records the Railway Mania of 1845. Fortunes of almost fabulous amount were said to have been realized by a few skilful manœuvrers; while vast numbers awoke, when too late, from the dream of glittering gains, to find themselves destitute.

Our readers may form some idea of the passionate eagerness for the investment of capital in railways which characterised this period, by a comparison of the number of Railway Bills carried through Parliament in the year 1845, with those previously obtained. It appears that up to the year 1840, about 1,100 miles of railway were actually constructed in Great Britain and Ireland. The year 1841 saw an addition to this aggregate of about 250 miles; about 180 were added in the

following year; while not more than 100 miles were laid down in 1843. In 1844, however, twenty-six Acts of Parliament were obtained for new railways, or branches of old ones, extending to a length of 797 miles, and the furor reached its climax in the following year, in which *two hundred and fifty* schemes were brought before Parliament, of which one hundred and twenty, comprising a total length of 2,841 miles, were duly authorized by the legislature.

Under these circumstances, we think it may fairly be considered a matter for just congratulation, that these great works were executed with so much conscientious regard to public safety, and to permanence, stability, and even magnificence, in all that concerned their constructive details. While directors and shareholders were absorbed in the fluctuations of the share-market, it might have been feared that the actual formation of the lines would have been hastily and superficially conducted. The vast majority of speculators were wholly uninterested in that construction: provided the shares reached a certain marketable value, they cared not whether the railway had any real existence at all. But the engineer had a nobler object in view,—the advancement of practical science, and the foundation of an honest and honourable fame. We trust we have shown in the foregoing pages, how nobly British engineers laboured in the vast field opened to them by the railway system. While feverish excitement reigned on the Stock Exchange, these men, resolute and cool, were battling with quicksands in the dark caverns of the tunnel, or creating firm ground upon the fluid moss, or rearing the stupendous viaduct; works which should bring luxury and convenience within reach of millions,

long after that feverish speculation had become part of the history of the past. The engineer worked for posterity, and we use no idle figure of speech, when we say that the pyramids of Egypt, or the temples of Thebes, were not built with a greater regard to perpetuity of duration, than the bridges and principal works of our railways.

It has been made a subject of complaint, indeed, that in England these works have been executed on a scale too grand and too costly; in America, it has been said, the extreme economy in the first construction allows a much more speedy remunerative profit to the shareholder: but we own we should be sorry to see the engineers of this country adopting any expedients which might secure economy in first cost at the expense of permanent stability. The "substantial" has ever been the distinguishing characteristic of British public works: and we trust that no narrow or short-sighted policy will ever prevail to the abandonment of that characteristic in the direction of British Railways. The safety of many lives may depend on the choice of materials and the accuracy of workmanship; and excellence in both of these can only be obtained by a liberal outlay.

It must occasion sincere regret, however, when this outlay is not attended with remunerative profit. This is unfortunately the case in more than one instance, in which peculiar difficulties have been most courageously encountered and overcome, for the sake of conferring very special advantages on the community. The cost of the Britannia Tubular Bridge was 500,000*l.*! The transit of mails, or troops, or other important travellers, to Ireland, is expedited many hours by that costly structure; while unhappily the whole amount of

traffic hardly pays (or at least has hitherto hardly paid) the current expenses.

It is not our province to suggest a remedy for this state of things; but we allude to it that we may vindicate railway directors generally from the charge of selfishness or undue parsimony in the construction of the lines; and that our readers may form some idea of the enormous cost, and too often the enormous *loss*, attendant upon the construction of those works which contribute so largely to their comfort.

In truth, if we turn, for one moment more, from the commercial to the social aspect of the system, we shall have reason for feeling sincere gratitude and thankfulness for the immense luxury we enjoy in railway travelling. We ourselves are old enough, and so are many of our readers, to recollect the time when the traveller from London to Edinburgh or Glasgow spent two consecutive nights on the road. So recently as the year 1838, we were obliged to travel during the greater part of *three* successive nights on a journey from South Devon into Yorkshire. Yet even that rate of travelling was deemed remarkably expeditious and regular. Men set their watches by the arrival of the North Mail at a well-known halting-place,—Catterick Bridge,—240 miles from London: the 24th hour since its departure from the General Post Office had rarely ceased chiming, when the notes of the horn were heard and the way-worn passengers flocked in to snatch a morsel of refreshment before encountering the biting wind along the Great North Road.

We have no wish to disparage the skill and enterprise which had brought coach-travelling to such perfection, and no desire to exaggerate its

discomforts or perils: but no one who remembers the misery of a *second* night in, or on, a stage-coach can fail to congratulate himself and his country on the mighty change of the last twenty years. The terrible weariness of sitting in a small four-inside coach, or on an outside seat crowded by other passengers: the indescribable numbness about the knees and joints, which it was impossible to shake off by change of posture: the intense cold (even in summer) of the early morning, from 2 to 5 o'clock: the annoyance of fumbling in your purse with icy fingers for the fee demanded by the coachman, who (you could not but acknowledge in your ill-humour) had driven you so well and so skilfully for the last 50 miles:—all these things, with many others, will be remembered by our readers with a pleasant sense of relief and of joy, that such miseries are gone by for ever!

Now, in rain or snow, in gale or calm, in sunshine or darkness, the train speeds along, without suffering or hardship to horse or man. In the closed carriages, the invalid, the tender woman, the delicate infant, the poor, struggling, half-clad mechanic, share with the healthy and vigorous perfect protection from weather. It is to the poor more than to the rich that we consider the Railway so great a blessing. The artisan, the domestic servant, the small tradesman,—these are the classes most benefited by the railway. A few years ago, the cost and duration of a journey placed travelling entirely beyond the reach of these classes: the roof of a coach was no place for the ill-clad or the weakly;* while the amount of the fare by coach,

* In an intensely cold night, a few years ago, we arrived by Mail at Gloucester, where time was allowed for supper. An outside passenger, repeatedly summoned to descend, still kept his seat after the coach had stopped. He was dead! dead from cold!

or of the cost of provisions if the slow wagon were chosen, deterred the humbler classes from many journeys which affection or interest might have prompted them to undertake.

Whatever may be the commercial future of the Railway System, we, for our part, doubt not for one moment, that this great "invention" or improvement is given by the Almighty as a blessing to man, and especially as a blessing to the poor. Already the immense number of third-class travellers proves how largely it is used by the poor; and the reader will join us in the wish with which we conclude;—that many a poor man's home may be cheered, many a poor man's heart gladdened, by the visit of the son or the daughter to whom the Railway has given such facility of transit: that his little store of comforts may be increased, and his general condition elevated, by the results of that system which we have endeavoured imperfectly to describe.

THE END.

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